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AMERICAN COAST ARTILLERY MATÉRIEL

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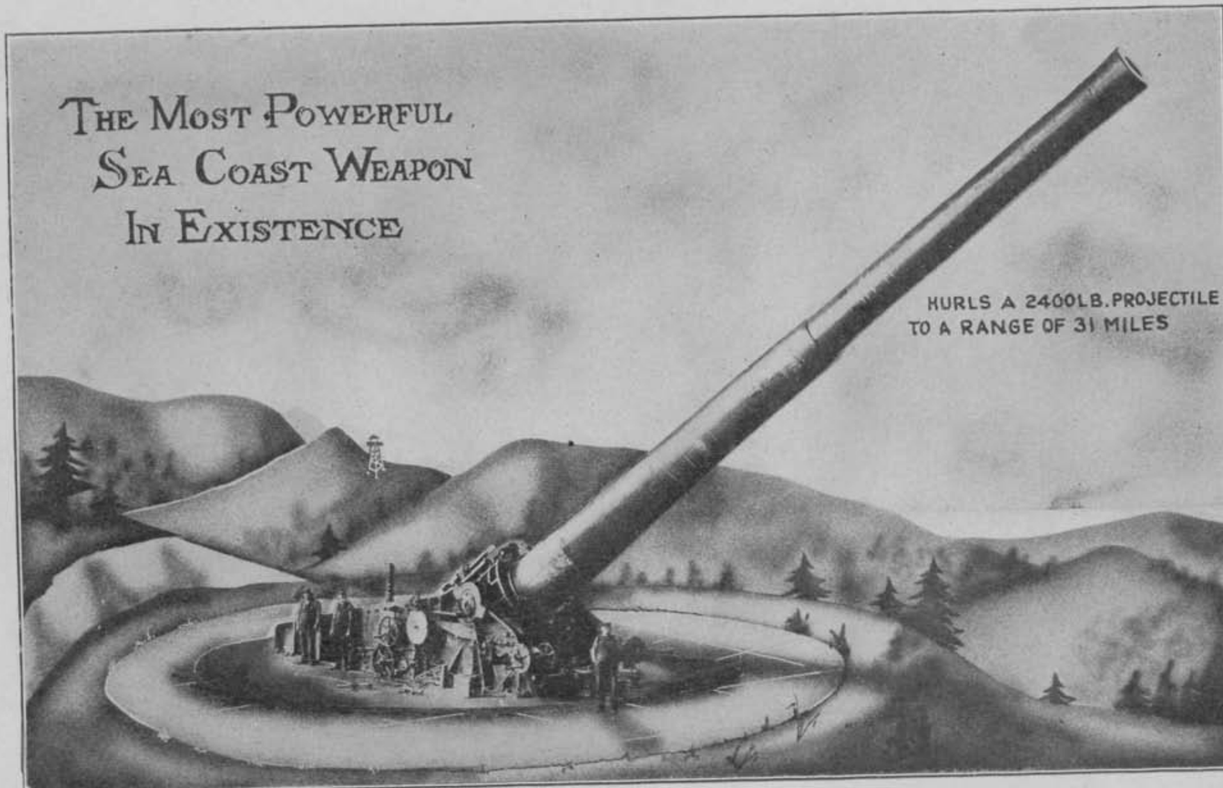
THE MOST POWERFUL
SEA COAST WEAPON
IN EXISTENCE
HURLS A 2400LB. PROJECTILE
TO A RANGE OF 31 MILES

ORDNANCE DEPARTMENT

Document No. 2042

Office of the Chief of Ordnance

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WAR DEPARTMENT,

WASHINGTON, *June, 1922.*

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BY ORDER OF THE SECRETARY OF WAR.

JOHN J. PERSHING,
General of the Armies,
Chief of Staff.

OFFICIAL:
ROBERT C. DAVIS,
Acting The Adjutant General.

PREFACE.

This treatise on coast artillery is supposed to deal primarily with American artillery and to include such data, description, etc., as can be given in one volume of reasonable size and still cover the history of development, the design and manufacture of a modern great seacoast gun and carriage, and detailed descriptions of existing seacoast weapons to the satisfaction of the casual student of the subject. Since America is relatively a new country, it is of course necessary to deal with artillery of any and every country in attempting to trace the history of the development of ammunition, guns, and carriages.

Careful survey of Part I will reveal that the history of the development of artillery in the years 1400 to 1850 is not a history of the development of the science or art of artillery, but simply a history of the development of the craftman's ability to cast or forge objects of greater and greater weight or more complicated design as to shape. The gun of 1850 is merely the gun of 1400 multiplied one hundred times or more in weight. The real development in artillery has taken place since 1850 and is coincident with the great and rapid development in every line of mechanical invention.

A discussion of American coast artillery hence does give a fair idea of the steps in the development of such artillery of all nations, because coast artillery has acquired its pronounced individual characteristics during this short period of rapid development. Before 1850 the same gun, carriage, and ammunition might be and were used indiscriminately on ships of war, in coast fortifications, or in the field for siege purposes.

The object of this treatise is to present to the student of coast artillery both a mental picture of the development of artillery in general from the thirteenth century, when it seems to have made its first appearance, through the various centuries as simply artillery, and through the past century when it has become sufficiently distinct to be termed seacoast artillery. In addition, it is desired to present as complete as practicable a description or outline of the procedure in determining the requirements of a modern high-power seacoast weapon, the various steps in design, and the important problems involved in the manufacture. A third part is devoted to a detailed description of each distinct type of mechanism found on all of the

seacoast weapons now in use in our various fortifications. It is the policy in discussing guns, carriages, and mechanisms to discuss each type in detail but once; that is, if a certain type of elevating mechanism is used on a number of carriages it will be discussed in detail but once. Thereafter merely a reference will be given to the detailed discussion.

There is no type of manufacture in America that involves the same severity of requirements as that required in the development, design, and manufacture of our modern seacoast weapons. It is to be hoped that the day will come when the Ordnance Departments of the Army and Navy will be recognized and will take their place as the pace makers in the art of machine design and will set the standards for the mechanical engineering world. In no other industry is it required to machine parts weighing as much as 100 tons to a degree of accuracy represented by a tolerance of only a few thousandths of an inch; nor is there an industry which deals with problems involving pressures so great as 40,000 pounds per square inch, or with the equally difficult problem of providing for the transmission during a very small fraction of a second of millions of foot-pounds of energy through parts which must continue to operate day after day with absolute accuracy into foundations embedded in the earth. When it is remembered that the modern high-power seacoast weapon will weigh a total of 1,000,000 pounds, must operate with such a speed as to permit the firing of one projectile weighing 2,400 pounds or more to a distance of 35 miles with such a degree of accuracy as to strike with telling effect a modern battleship, some little appreciation of the problems of design and manufacture can be secured.

It is hoped that this presentation on the basis of the general development and history of artillery, the determination of requirements, the design and manufacture of a modern seacoast weapon, and the detailed description of all distinct types of mechanisms will serve the purpose of giving to the early as well as the advanced student such a comprehension of the problems of development, design, and manufacture of seacoast artillery as will enable him to render more efficient service in any branch of the Army having to do with any type of artillery.

The information contained herein has been secured from the sources listed in the bibliography, from inspection of the material discussed, and from consultation with engineers responsible for various requirements and designs or familiar with them. Paragraphs 37 to 60 were prepared by Doctor (Colonel) Storm, of the Ammunition Division, and have been previously published in No. 10, Volume II, of Army Ordnance.

H. W. Miller,
Lieutenant Colonel, O. R. C.

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Part I.

HISTORY OF THE DEVELOPMENT OF ARTILLERY.

GENERAL INTRODUCTION.

1. It is intended in this history of the development of artillery and ammunition to point out, at least briefly, the various steps that have led from the invention of discovery of gunpowder to the present state of perfection in ammunition, guns, and carriages. It may be well to mention in advance a conclusion to which one seems certain to come in the extended study of this development. All indications are that practically each step in the development was forced by circumstances and actually became a recognized advance in the art many years, sometimes centuries, after the time when it might have been adopted to the advantage of all concerned. For example, hand rifles had been perfected to the point of rather efficient use for sporting purposes as early as 1800. No soldier nor those responsible for issuing them to soldiers would have thought of using an Army musket for hunting game if he could secure a rifle. In spite of the known fact that only one in each 450 bullets fired from an Army musket would find its mark in war, it was used in our wars of 1812, 1845, and even in the great Civil War of 1860–1864. The rifle had been introduced into the French Army in 1800, but Napoleon withdrew it, probably because of the great amount of time required for loading, and it was not again used by them until 1870. The British did not adopt it until about 1860. And during all of this time it was the weapon par excellence for sporting purposes. Since this is an example of the general tendency in the development of the art or science of artillery one should not be surprised at even the present backwardness of it in any particular respect. These comments are entered as illustrations of tendencies and not as a criticism of any organization or individuals. It is probable that we will always have our spurts of development just after a great confiict which points out tragically our backwardness in any branch of the science. This is certainly true at the end of the World War.

2. It has been particularly difficult to trace the earliest development in ammunition and likewise the corresponding development in artillery. There are numerous reference in many more or less

modern books to apparent records of the invention or discovery of gunpowder in the fourth to the sixth centuries A. D., and to the use of this substance in some sort of guns, pots, or mortars in the sieges of such cities as Mecca, Constantinople, etc., during these same centuries. The first siege of Mecca occurred in 683 A. D., and at that time the sacred Black Stone was broken by fire. References can be found to the fact that in this siege the mixture familiarly known as "Wildfire" was used by the besiegers and that these balls of pitch, naphtha, and sulphur were hurled over the walls by some sort of mechanical projecting engine. There is no reference, however, that one seems warranted in accepting as indicating the existence and use of gunpowder at that time or in that siege. In fact, it seems certain that all of those references that have been interpreted as proving that gunpowder existed before the thirteenth century actually refer to the various incendiary combinations in more or less common use, none of which actually contained saltpeter, a necessary ingredient of what we know as gunpowder. Since the most pains-taking research seems to clinch this conclusion, there seems no choice but to start with the development of artillery after the proved discovery of gunpowder in the thirteenth century. In short, the "beginning" for artillery of any description is approximately in the year 1250 A. D.

3. As an indication of the development that had taken place prior to 1885 we cite the following paragraphs from Edgar S. Maclay's "History of the Navy," Volume II:

In 1885 the armament of our warships consisted principally of 9-inch smoothbore guns, 8-inch muzzle-loading rifled guns, and converted 80- and 60-pounder breech-loading rifled guns. The 8-inch guns were 11-inch cast-iron smoothbore Dahlgrens, having a rifled wrought-iron tube inserted into the bore. The 100- and 60-pounder Parrott guns were converted into breech-loading 80- and 60-pounders. In 1885 there was no plant in the United States capable of making forgings for guns of more than 6-inch caliber, while steel shafting, torpedoes, armor, and machine guns also had to be purchased abroad. With a view of remedying this serious defect the Gun-Foundry Board in 1883 visited the principal gun and steel establishments in the United States and abroad, and in the following year recommended that the Government maintain gun factories capable of turning out the largest calibers after the most approved patterns, and that private firms be encouraged in making steel forgings and material for guns. In January, 1886, the Board of Fortifications, composed of civilians and Navy and Army officers, approved the report of the Gun-Foundry Board, and in August of that year four millions were appropriated for a steel-armor plant and $2,128,000 for guns. In May, 1887, contracts were signed with the Bethlehem Iron Co. for gun forgings and armor plates. This plant has been developed until it is one of the best establishments of its kind in the world and can produce forgings for 16-inch guns. The Naval Gun

Factory was begun at the Washington Navy Yard in 1887 and has been constantly enlarged until it is now a most complete establishment.

4. During the intervening six centuries the development went forward steadily, if somewhat laboriously and at times at only a snail's pace. It will be pointed out later that the development during the first century and a half was almost as spectacular as that of the last 70 years. The significant point to be remembered in connection with what has just been quoted from Maclay is that although the development in the various elements which together make up the science or art of artillery took place spasmodically, seldom in concert, sometimes at a rapid rate and sometimes a slow rate, somehow in about 1850 nearly all of the elements were about evenly developed and the essential principles which had been obscured for so many centuries were clearly recognized. It seems best to take up the development of each of the so-called elements separately, hence the method of treatment that follows:

AMMUNITION.

INCENDIARY MATERIALS.

5. *Greek fire.*—668 A. D.—There seem to be a great number of combinations which come under the name of Greek fire. Further, it seems certain that records of the use of many of these terrifying or incendiary combinations have been misconstrued as indicating the existence and use of what we term black powder many centuries before saltpeter, the essential ingredient of black powder, had been collected and purified in sufficient quantities to be known as a distinct substance with peculiar properties. Strictly speaking, Greek fire was apparently a liquid which was projected from some sort of tube and has an analogy in the liquid fire employed by both sides in the recent World War in connection with the device or machine known as a flame projector. In speaking of this substance with the name correctly applied as counter to the use of the name for all sorts of incendiary substances, Marshall says, on page 12, Volume I, of his treatise on Explosives:

The one notable exception to this is the "Greek fire" or "sea fire," the secret of which prevented the conquest of Constantinople and Europe by the Moslems for several centuries. About the year A. D. 668, some 46 years after the flight of Mohammed from Mecca to Medina, the Arabs, still at the height of their conquering enthusiasm, commenced to beleaguer Constantinople by land and sea, when an architect named Kallinikos fled from Heliopolis in Syria to the Imperial City and imparted the secret of the "sea fire." This repeatedly spread such terror and destruction among the Moslem fleet that it was the principal cause of the siege being eventually

raised after 7 years. In A. D. 716 to 718 the Arabs again appeared before Constantinople with 1,800 ships, but again were defeated by the fire so effectually that after a stormy passage only 5 galleys re-entered the port of Alexandria to relate the tale of their various and almost incredible disasters.

Russian naval forces were similarly defeated in 941 and 1043, and the Pisans at the end of the eleventh century. What, then, was the nature of this "sea fire?" From the contemporary accounts we know that it was discharged from tubes or siphons in the bows of the ships, but its mode of preparation was kept a close secret, and it was never used successfully by any but the Greek rulers of Byzantium. There appears to be no doubt that naphtha was the principal ingredient, and it may also have contained sulphur and pitch. Col. H. W. L. Hime came to the conclusion that it must have been mixed with quicklime, the slaking of which by the sea water raised the temperature to the ignition point of the sulphur. I have made a number of attempts to produce ignition in this way, but although a fairly high temperature was reached, the sulphur never caught fire. The heat set free by the slaking of the lime would be ample to raise the temperature to the ignition point if there were no losses of heat, but the reaction is a slow one compared with an explosion, for instance, and consequently much of the heat is dissipated. It seems more probable that the naphtha was simply discharged from a squirt or fire engine (sipho), and that it was ignited by means of a flame in front of the orifice, and that the secret consisted in the method of constructing the squirt or pump and of using it so as not to injure the users.

6. *Wildfire.*—It has been mentioned above that numerous combinations of incendiary materials in more or less solid form were included under the name of Greek fire. Marshall thinks these combinations may more properly come under the name of wildfire. They included combinations of sulphur, pitch, naphtha, resins, and other substances that burn quite readily. Later when saltpeter became known and was available in quantity it was probably added and had the effect of making the mass burn more fiercely.

7. Such mixtures were much used by the Moslems and probably were known to all so-called civilized nations who were interested in conquest or in the defense of cities. The Moors apparently used combinations containing saltpeter in their various battles and sieges in Spain around 1250. The use of wildfire is mentioned frequently also in connection with the Crusades, the Moslems being the principal users. One combination mentioned under the heading of "Flying fire" in a translation of the Liber Ignium of Marcus Graecus, translated about 1300, contained resin, one part; sulphur, one part; and saltpeter, two parts. These were dissolved in linseed oil and put into a hollow reed or piece of wood. There is no mention of exactly how it was used, but it was apparently an incendiary instead of a terrifying agent.

8. On page 6, Volume III, of Etudes sur le Passe et l'Avenir de L'Artillerie, UF 155–F8–N1, there is a statement to the effect that "In 969 A. D., the second year of the reign of Tai Tsow, founder of the dynasty of Song, the prince was presented with a composition which burned with a flash and carried a long distance." One can not tell from this statement whether perchance it was actually gunpowder and was able to project an object from a vessel or whether, on the other hand, it was simply a more or less solid mass that burned vigorously as it traveled through the air after being projected by some mechanical engine. Marshall thinks that saltpeter was discovered by one of the oriental nations, and it is possible that the combination referred to was one containing saltpeter. It could hardly have been gunpowder, however.

9. *Crakers and Roman candles.*—In the translation of the Liber Ignium of Marcus Graecus, mentioned above, there is another formula, as follows: Sulphur, one part; vine or willow charcoal, two parts; and saltpeter, six parts. These were to be rubbed down on a marble slab and the resulting mixture, which may properly be termed gunpowder, put into a case or vessel in different manners, according to the effect to be produced. "A case, short and wide, filled half full and bound with strong wire," was specified for the making of a loud noise. This was the original of our "firecraker." Another case, "long and thin, and filled with the mixture well rammed in," served either as a rocket or as a Roman candle. It could probably be used as either. There is nothing to indicate which purpose it served. It is interesting to note, however, that in the use of these incendiary, terrifying, and noise-making combinations containing saltpeter, in the latter part of the thirteenth century they were gradually coming to a discovery or recognition of the power of the mixture of sulphur, charcoal, and saltpeter to project an object from a vessel. It may be of interest to requote from Marshall's book several paragraphs discussing the use of fire pots:

> At that time use was made of the "ho-pao," or fire pao, called "Tchin-tien-loui," or "thunder that shakes the sky." For this purpose an iron pot was used, which was filled with "yo." As soon as a light was applied, the pao rose and fire spread in every direction. Its noise resembled that of thunder and could be heard more than 100 lis (33 English miles); it could spread fire over more than a third of an acre. This fire even penetrated the breastplates on which it fell.
>
> The Mongols constructed with oxhides a passage which enabled them to reach right to the foot of the rampart. They commenced to sap the walls, and made holes in them in which they could remain sheltered from the men above. One of the besieged proposed that they should hang fire paos from iron chains and let them down the face of the wall. When they reached the places that were mined the paos burst and shattered the enemies and the oxhides, so as not to leave a vestige of them.

In addition, the beseiged had at their disposition some "arrows of flying fire" (fei-ho-tang); to an arrow was attached a substance susceptible of taking fire; the arrow flew suddenly in a straight line and spread flames over a width of 10 paces. No one dared approach. The fire paos and arrows of flying fire were much feared by the Mongols.

10. This arrow may have been a squib or a rocket, or merely an arrow to which a saltpeter mixture was attached. The effects described could hardly have been produced without the use of saltpeter nor the great noise without an explosive, but we need not take literally the statement that it could be heard 33 miles away.

11. By A. D. 1250 the Chinese had made a further advance. The same annals state:

In the first year of the period Khai-King was made an appliance called "tho-ho-tsiang"; that is to say, "lance with violent fire." A "nest of grains" was introduced into a long bamboo tube, which was set "light to." A violent flame came out and then the "nest of grains" was shot forth with a noise like that of a pao, which could be heard at a distance of about 500 paces.

This was evidently the device now known as a Roman candle.

12. *Black powder.*—The original propellant has, so to speak, served its period of maximum usefulness and is now used rather sparingly for very special purposes. There is reason to believe that the engineers of Chingis, the Mongol conqueror, made use of some combination of saltpeter, sulphur, and charcoal in destroying the fortifications, walls, etc., of some of the Persian cities. Several writers on the subject of explosives think that the formulas used by the Chinese in making black powder in the thirteenth century are identical with the formulas used in compounding the powders used in the fireworks that have until a very few years ago been imported from China. Apparently the ancient formulas were either passed down to these writers in certain ancient scripts, or as mentioned in one instance some of the powder made in the thirteenth century was found in some excavations in the last century.

13. It would be safe to assume that black powder has been made and used before the dates given in the first descriptions of it. Historians were not so much interested in the history of development then as we are now and many descriptions that now assist us in tracing a development were included only incidentally in the writings in which we find them. When saltpeter and black powder were first made, there were probably no new names invented for them, and it is difficult to recognize the substances in the names applied to them. Saltpeter means salt of the rock, nitrum means soda or any other white efflorescence, gun was originally applied to a mechanical propelling instruments, and powder has no significance in the matter of a propellant. It is easy to see, then, how confusing references can

be and how careful one must be in accepting references, no matter how apparently definite, as indicating the existence and use of what we now know as black powder and a gun before certain dates.

14. Although one seems warranted in believing that the Chinese were using black powder in 1218, the indications are that it was being used as a blasting agent instead of as a propellant. In 1249 Roger Bacon wrote the following account in his "De Secretis" and "Opus Tertium":

> From the flashing and flaming of certain igneous mixtures and the terror inspired by their noise wonderful consequences ensue. As a simple example may be mentioned the noise and flame generated by the powder, known in divers places, composed of saltpeter, charcoal, and sulphur. When a quantity of this powder no bigger than a man's finger is wrapped up in a piece of parchment and ignited it explodes with a blinding flash and a stunning noise. If a larger quantity were used, or if the case were made of some solid material, the explosion would, of course, be much more violent, and the flash and din altogether unbearable.
>
> If Greek fire, or any fire of the same species, be employed, nothing can resist the intensity of its combustion.
>
> These compositions may be used at any distance we please, so that the operators escape all hurt from them while those against whom they are employed are suddenly filled with confusion.

This indicates that black power was known to him, but again as a noise-making agent and perhaps as a blasting agent, but not as a propellant.

15. To summarize, then, it would seem reasonable to accept the date of 1200, as discussed later, and recognized as the certain date of the recognition of the characteristics of saltpeter, as the approximate date of the earliest use of black powder for any purpose. The date of 1250 seems reasonable for the approximate date of its first use as a propellant, both because of the mention by Roger Bacon of its ability to produce a great noise when confined in a vessel and fired, and because there are good records, UF 155 F–8 N–1, volume 3, page 28, to indicate its use by the Arabs in 1295 in some sort of tube for the propelling of lances, and other records even more reliable to indicate the rather general use of even so advanced a weapon as a cannon before 1324. If guns of any description were in use in 1295, they were not developed all at once, and the fact that this is the first date mentioned makes it certain that they were used before then. The date 1250 may not be correct, but it seems to have some foundation, and for the sake of reference in this treatise, at least, it will be used as the probable date of the first use of black powder as a propellant. The references to the use of powder in guns, mortars, and longer cannon are so numerous for the fourteenth century that one must believe that there had been an appreciable period be-

fore 1300 for the slower development and spread of the knowledge throughout Europe and Asia of the properties of powder and methods of constructing guns and cannon.

16. *Saltpeter.*—On the discovery of saltpeter, the recognition of its properties, and the refining of a sufficient quantity to use hinged the beginning of the development of what we now term artillery. There could be no such thing as gunpowder without some substance that would supply the oxygen for the partial or complete combustion of any other constituents of the mixture when confined in a vessel. Saltpeter was the first known oxygen-supplying agent, hence we need simply search for information of the date of discovery or isolation of saltpeter to determine the absolute date before which there could have been no such substance as gunpowder and no such instrument as a gun. It is doubtful whether available records will indicate the exact date of the discovery of saltpeter. As known then the saltpeter was formed in the decomposition of animal and vegetable matters. Under certain conditions it formed an efflorescence on the ground, sides of buildings, etc., and was called "Chinese snow" by the Egyptians. The first clear reference to saltpeter is in the writings of a Spanish Arab, Abd Allah ibn al-Baythar, who died at Damascus in 1248. It seems probable that it was first known in those countries which had pronounced wet and dry seasons during which times the vegetable and animal matters could decompose and later the resulting saltpeter would appear as the efflorescence. Such countries would be Egypt, India, China, Arabia, etc. Since it is still used in India as an edible salt it is probable that this was its first use. Its second probable use was as a medicine. It is significant that Chingis, the Mongol conquerer, brought Chinese engineers with him in 1218 to reduce the fortifications of the cities of Persia, and they made use of combinations employing saltpeter.

17. Marco Polo, the well-known traveler of our early histories, was in the Far East from about 1274 to 1291. He says concerning the city of Chan-Glu in Part II, Chapter I, of his book:

"In this city and the district surrounding it they make great quantities of salt, by the following process: In the country is found a salsuginous earth; upon this when laid in heaps they pour water, which in its passage through the mass imbibes the particles of salt, and is then collected in channels from whence it is conveyed to very wide pans not more than 4 inches deep. In these it is well boiled and then left to crystallize. The salt thus made is white and good, and is exported to various parts."

18. There is no indication that the salt thus obtained was used as other than an edible salt, but the soil in this region is rich in saltpeter, hence whatever its use the salt obtained did contain saltpeter and its properties could have become known. It seems prob-

able that the Arabs and Egyptians knew saltpeter in a fairly pure state about 1225. If the records giving this information and likewise the information with reference to the use of saltpeter by the engineers of Chingis in 1218 be accepted as reliable, it would seem reasonable to set up the year of 1200 as the date of the beginning of the use of saltpeter. It may have been known in 969, as stated in paragraph 8, but it is not referred to specifically there. On page 20, Volume III, of the reference just mentioned, UF 155 F–8 N–1, the statement is made that saltpeter was known to the Arabs in 1240, but then only as a medicine. It may be of interest to mention further the development of the processes of securing saltpeter from the earth and from the atmosphere during the centuries since its first discovery. Until the middle of the nineteenth century all saltpeter was obtained from earth and deposits in cellars, caves, and similar places where it had formed naturally. About 200 feet from Natural Bridge, in Virginia, there is a small cave known as Saltpeter Cave, from which it is understood a considerable quantity of saltpeter was secured for making black powder in Revolutionary and other days. One is told by the French people of Tours, France, that the portion of the cathedral which has been destroyed on the river side was so destroyed in the days of the French Revolution for the purpose of extracting saltpeter from the soft limestone rock. This saltpeter was used by the revolutionists in the making of gunpowder. It is understood, likewise, that the principal reason for the rapid erosion of the stone used in the construction of so many French structures, cathedrals, etc., is that the stone contains a high percentage of saltpeter, which leaches out and causes crumbling of the surface under the action of atmospheric moisture, rain, etc.

19. It has been mentioned before that saltpeter was originally secured in those countries where they have pronounced wet and dry seasons and where vegetable matters might decompose and the resultant nitrate dry out on the surface of the ground or stone in the dry season. In Europe there is no such sharp division of seasons. The decomposition of animal or vegetable matter continues throughout the year, and the resultant nitrate seldom if ever appears as in dry countries. Since it was of the greatest importance in every country to have a sufficient supply of saltpeter to supply its needs, especially in time of war, the measures necessary for its production required were given the support of numerous royal decrees and orders. It is understood that in France special officers termed saltpeter commissioners were appointed in 1540 to search for and extract saltpeter for all sorts of purposes. This decree was renewed in 1572, and at any time thereafter when France was faced by a serious war. It is interesting to know that the men working under this

decree operated on the earth, stables, sheep pens, cattle sheds, cellars, etc., and on the plaster, stonework, rubbish, etc., of houses which were demolished. They were given the right to gather material everywhere with scrapers and brushes in houses and with any necessary implement in places not inhabited. If buildings and walls were to be pulled down, it was necessary to give these saltpeter workers notice, who then had the opportunity to state which parts they wished reserved.

20. One can gather some idea of the importance of this industry during the fourteenth, fifteenth, and sixteenth centuries when he knows that the saltpeter workers were given the privilege of setting up the vats and apparatus practically wherever they thought fit—in public halls, private yards, etc. The local authorities were required to supply fuel for the distillation and were likewise required to transport the vats and the saltpeter to the refinery. Each locality was visited periodically—that is, once in every three or fours years. Saltpeter was also obtained from artificial nitrate beds composed of earth, animal and vegetable matter, ashes, miscellaneous refuse, lime and soft stone. This was all collected in heaps and mixed with twigs to permit the access of air. It was necessary to turn the mass over from time to time to hasten nitration. The nitrate which was formed in the mass was extracted with water.

21. The state of affairs in France with reference to saltpeter in the early part of the seventeenth century is given very well by Marshall in the following paragraph from page 54 of "Explosives":

> In the reign of Louis XIII (1610 to 1643) the annual crop of saltpeter amounted to 3,500,000 pounds, but it gradually diminished in the eighteenth century largely on account of the strong objection the people naturally had to the presence of saltpeter workers in their houses and domains. In 1775 the quantity had fallen to 1,800,000 pounds, and half the annual requirement was imported from India. If it had not been for the many privileges the nitrate workers enjoyed, the home product could not have competed at all with that imported from India. In 1789, the year of the fall of the Bastille, a great effort was made, however, to revive the industry, and 3,000,000 pounds were obtained. In 1791, however, the National Assembly proposed to abolish the privilege of the saltpeter workers, but war broke out, the harbors of France were blockaded, and it became necessary to produce in the country all the saltpeter for the powder required. The recent increase of chemical knowledge and the hearty cooperation of the greater part of the population made it possible to produce 16,000,000 pounds in a single year and 5,000,000 in the next. The whole organization was placed under the control of the department of "Pondres et saltpetres," which still continues to regulate matters concerning explosives.
>
> When peace was finally reestablished the renewed competition of Indian saltpeter dealt a severe blow to the industry in France, and in 1840 the bounties were abolished, but it struggled on until the

exploitation of the sodium nitrate deposits in Chile and the potash deposits in Germany in the second half of the nineteenth century led to the production of artificial saltpeter. The consequent reduction of price almost entirely killed the French saltpeter industry, and in 1870, when a scientific committee was engaged in providing Paris with all stores necessary for its defense, Berthelot could find only one or two small producers in Champagne.

22. In England practically all of the saltpeter seems to have been imported until the sixteenth century, much of it coming from Spain. Regulations similar to those made in France were put into effect in 1515; however, Hans Wolf, obviously a foreigner, was appointed to be one of the royal gunpowder makers in the Tower of London and elsewhere. As with the French saltpeter commissioners, he was permitted to go from place to place, determine where saltpeter might be secured, and proceed to operate with royal authority, but with the understanding that he was to compensate the owners of the property. In 1531 Thomas Lee, a royal gunner, was appointed principal searcher for saltpeter and maker of gunpowder. It is interesting to note that considerable competition developed between the saltpeter workers and soap boilers for wood ashes, which were practically the only source of potash and were required for the conversion of sodium nitrate into potassium compound. In 1534 the saltpeter searchers were given preemption of the ashes over the company of soap boilers by royal decree, on the ground that saltpeter was a greater necessity to the public than soap. The monopoly of saltpeter was abolished in 1641, at the same time that the monopoly on the manufacture of gunpowder was abolished.

23. Saltpeter was imported from India as early as 1625 and powder mills set up in Windsor Forest about the same time for the manufacture of gunpowder from the imported saltpeter. In 1693 the importation had gone to the extent of 500 tons and ever since then the amount annually imported has increased tremendously. It is still secured from the earth, refuse, etc., in India by methods as crude if not more so than the methods employed in France and England in the seventeenth century. Since there is such an excess of labor of the very low order required for this extraction, these crude methods will probably persist in India and China for many years to come. Bihar is the principal source of saltpeter in India, but considerable quantities come also from the United Provinces and the Punjab. Most of this is exported. At Calcutta in 1850 the amount annually exported averaged about 30,000 tons. At present it is only about 20,000 tons. The crude, bitter, and impure salt is still used as common eatable salt.

24. The Plain of Tamarugal in Chile is one of nature's gigantic concentrating vats for the collection of nitrate. It lies between the Andes and low coast hills, at a height of about 3,000 feet above the

sea, within the Tropics. There is comparatively little rain there, but once in every five to seven years the entire plain, which is 45 miles wide, is flooded. The plain slopes gently toward the coast hills, and since the water can not escape through any natural outlet it must evaporate. All of the nitrate which the flood water has dissolved from the entire plain is left deposited in a comparatively small area. The famous Chile nitrate beds are therefore the concentrating pocket of a vast area. The nitrate is principally sodium and very little potassium, in the proportion of approximately 94 per cent sodium nitrate to 1.5 per cent potassium nitrate, with numerous chlorates. The nitrate from these beds has been exported since approximately 1830, and the supplying of nitrate from these sources has developed into a tremendous industry.

25. The greater part of the saltpeter used in the manufacture of black powder to-day is secured by the conversion of Chile nitrate, which is sodium nitrate, into potassium nitrate. One of the methods employed in this conservation is to mix potassium chloride with sodium nitrate in distilled water; the liquid is boiled for approximately one-half hour. To complete the reaction which results in the forms of potassium nitrate and sodium chloride this liquid is then run into cooling tanks, and since potassium chloride is less soluble at lower temperatures than sodium chloride, it begins to crystallize out in a satisfactorily pure state when the liquid has cooled to a certain point. The crystals obtained are redissolved in distilled water and permitted to recrystallize, in which procedure the amount of sodium and magnesium chloride is reduced to at least 0.05 per cent. The resulting saltpeter is then fit for use in the manufacture of black powder.

26. *Camphor.*—The first makers of black powder experienced considerable difficulty in rendering the mixture uniform and in keeping it so. It seems that on occasions the ingredients were even sent separately to the field of operations in war and mixed by the master gunner on the spot. One would not wonder at the lack of uniformity of the results even under the most favorable conditions as to the accuracy of the bore of the gun and the fit of the projectile. But if one combines an irregular gun bore, a stone projectile, and powder mixed on the spot and loaded under varying conditions, the result can easily be imagined. And the result was just as one would expect; that is, that the most effective element of artillery fire of the earlier centuries was the noise. But some effort was made to render the mixture uniform and to keep it so. In the Codex Germanicus of the fourteenth century there appears this formula: "If you want to make a good, strong powder, take 4 pounds of saltpeter, 1 pound of sulphur, and 1 pound of charcoal, 1 ounce of sal pratica and 1 ounce

of sal ammoniac and one-twelfth part of camphor. Pound it all well up together and add spirit of wine and mix it in, and dry in the sun. Then you have a very strong powder, of which 1 pound will do more than 3 pounds otherwise, and it will keep well and becomes better with time." In another part of this same reference we find the statement that "When there is no camphor, it crumbles and easily spoils. But the camphor holds all powder together and is also strong and quick in all powder, if one puts it in."

27. The early makers of black powder did not recognize the reaction that took place on the burning of the three principal ingredients and hence did not know that the elimination of air spaces and the keeping of particles of saltpeter, charcoal, and sulphur in juxtaposition were prime requirements. They probably could see, however, that mixed powders settled out noticeably on being handled and that this settling out did not occur when some such a gum as camphor was mixed in. They had the erroneous idea that the camphor in itself added power, when in fact it merely cemented the ingredients more closely together and thereby permitted a greater speed of combustion and consequent greater pressure in the gun. The sal practica mentioned was an efflorescence resulting on the surface of an earthen vessel from placing in the vessel a mixture of saltpeter, camphor, and sal ammoniac, dissolved in alcohol.

28. *Serpentine.*—The original ununiform powdery mixture of the three principal ingredients was termed "serpentine," this name being borrowed from the small cannon in which it was used. Such gunpowder was first made by simply pounding up the constituents and mixing them in a mortar. It was of very uncertain powder and had the bad characteristic of seriously fouling the gun. In 1587 Bourne, in his Art of Shooting in Great Ordnance, said, "The powder rammed too hard, and the wad also; it will be long before the piece goes off. * * * The powder too loose * * * will make the shotte to come short of the mark. * * * Put up the powder with the rammer head somewhat close, but beat it not too hard." Such powder had likewise the disadvantage of absorbing moisture rather rapidly, and if left in large guns for long periods, as was frequently the case with the great bombards which were loaded with stone projectiles weighing as much as 700 pounds (Brit. 20, 190, a), it could easily deteriorate to the point of being practically powerless. These disadvantages had to be tolerated, however, until the practice of cementing the mixture together with such gums as camphor and the molding of the constituents into cakes when mixed with water had been adopted. Even then the fine powder continued in use under certain circumstances, as will be mentioned later.

29. *Corned, caked, and grained powders.*—It is uncertain whether the forming of the constituents of black powder into grains or cakes

was accomplished first through the use of camphor or water. At a very early date, probably before the middle of the fifteenth century, cemented and molded powders were in use and their superiority to the powdered variety known. The earliest known reference to "corned" or lumped powder is in the "Firebook" of Conrad von Schongau, under the date of 1425. It was known then that powder in such form, made from breaking into pieces the cakes formed by mixing with water after grinding in the mortar, fouled guns less than the fine powder and had greater power. It may or may not have been known why it had greater power. No reference makes this certain. It is interesting to note here, however, that already the development of artillery was waiting on the metallurgist. In 1560 Whitehouse, in his Certain Waies for the Ordering of Soldiers in Battleray, says: "If serpentine powder be occupied in handguns, it would scant be able to drive their pellets a quoits cast from their mouths. And if handgun powder (corned powder) should be used in pieces of ordnance, without great discretion, it would quickly break or mar them." Here we see that the pressures developed by the more rapid burning molded powder had exceeded the strength of the metals used in cannon—at least as they were then designed.

30. Since this early beginning of the molding of powder into cakes, grains, etc., we have passed through the processes of passing the grains through sieves and sorting them according to sizes, 1525; the compressing of the original cake under a hand press to secure greater density, 1784; under a screw press in 1789; and under a hydraulic press in the nineteenth century. This compression evidently produced a very hard cake, which was broken down by wood mallets and the resultant grains of various size took on a polish on being tumbled in a revolving cylinder or on being shaken in a pan or sieve. The powder rubbed or scoured off in the polishing would be remodeled into new cakes. This latter process of manufacturing black powder is described at considerable length by Louis de Toussard in his Ancient Ordnance, written at the request of Gen. George Washington, then President, under whom he had served in the Revolutionary War.

31. Cannon had continued to increase in power from century to century, though they decreased somewhat in size, at least of the bore. We probably will never see again a cannon of 36-inch bore, such as the great stone-throwing Russian Mortar of Moscow. The 21-inch mortar designed and manufactured, but not used, by the French Government during the World War is considered somewhat of a monstrosity and may never be used in warfare. In 1850 the American Army possessed 13-inch mortars and smoothbore howitzers and guns of as much as 12-inch bore. The requirements in ammunition had become considerably more severe, and although the shell did not fit

the bores of such guns accurately and very little accuracy of fire could be expected, some real thinking was being done in bringing the black powder up to requirements. General Rodman, of the Ordnance Department, conducted a series of experiments in the molding of black powder into large grains and in the producing of perforated grains of such powder between 1857 and 1869. Grains of specific sizes were adopted for guns of the various diameters, and the powders of the various sizes were termed "pebble," "mammoth," "perforated prismatic," and "perforated cylindrical."

32. A further step was taken in the attempt to regulate the rate of burning of black powder by varying its composition. The great difficulty that had been experienced with cannon in the last century or two before 1850 was the bursting under the pressures developed from the use of grained black powders. Some advance had been made in the design of cannon and perhaps in the composition of the materials. Iron cannon were not in great favor; at least they were not so popular as bronze cannon. And even between 1850 and 1870 many interesting and promising experiments in the rifling of cannon left unfavorable impressions because the cannon persisted in bursting after so few rounds under the higher pressures developed under the more perfect obturation of the experimental projectiles. The further development in black powder was in the modification of the charcoal constituent. It was always recognized that the charcoal used in the manufacture of black powder should be made from soft woods, e. g., alder, willow, aspen, hazel, poplar, oleander, yew, as well as straw, hemp stems, vines, etc. The final development, however, was in the partial burning of the charcoal, thereby producing a brown charcoal and a powder known as "cocoa" powder which burned more slowly and with greater uniformity. The result was less pressure in the gun without loss of projecting power. This was probably the final step in the development of such powder, for close on its heels came the successful development of the now almost universally used "smokeless powder," in 1886, which put black powder out of business as a propellant.

33. *Manufacture.*—The methods of manufacture and the composition of black powder have passed through many interesting stages. An early formula as given by Marcus Graecus in 1300 calls for 11 per cent sulphur, 1 part (by weight probably); 22 per cent vine or willow C., 2 parts; 66 per cent saltpeter, 6 parts. The formula commonly used in America as well as in many other countries at present calls for sulphur, 10 per cent; charcoal (brown), 15 per cent; saltpeter, 75 per cent.

The original powder comprised a loose mixture of the three ingredients. The closest approximation to this at the present time is the powder used in the cheapest of fireworks. Even this, however,

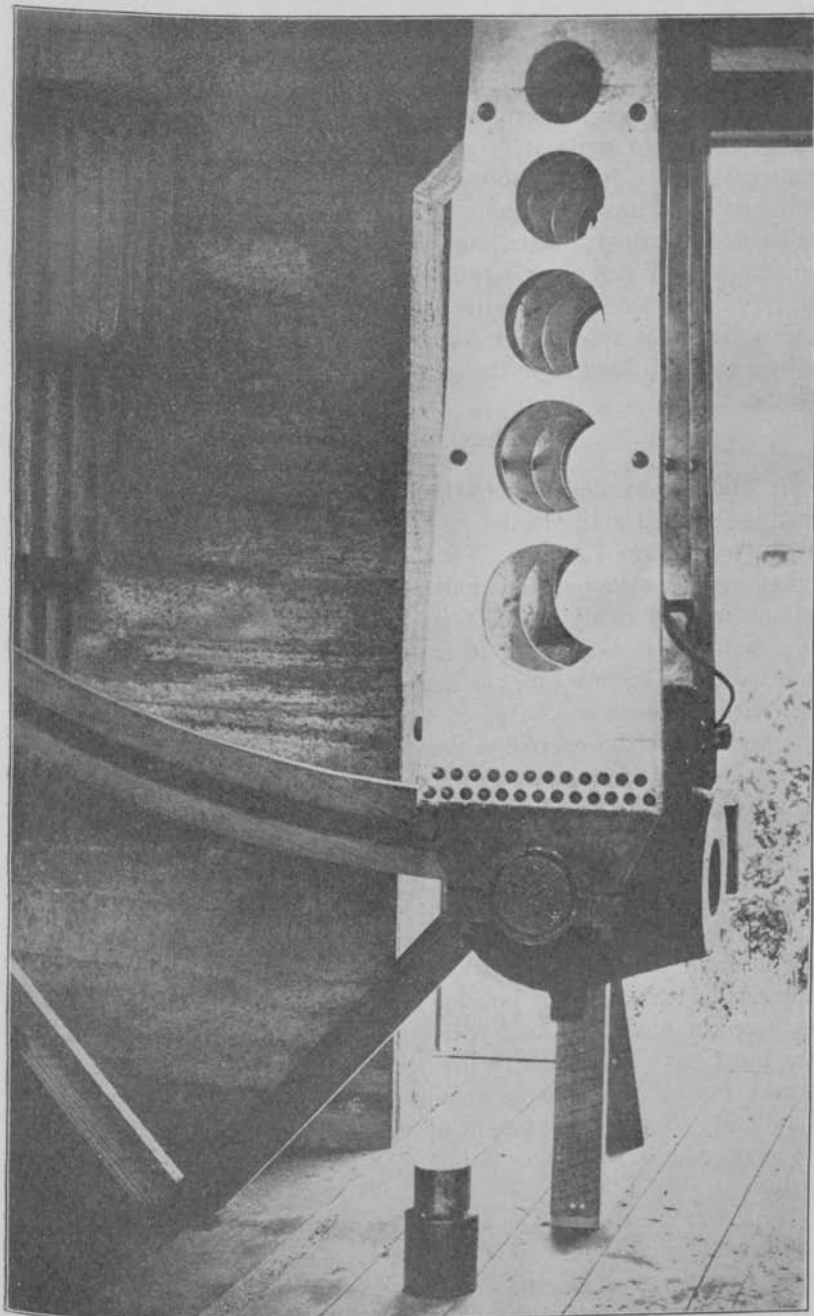
is generally a dust resulting from the pulverizing of a partially caked mixture. For other purposes—blasting, small rifle charges, schrapnel, cannon ignition, etc.—the powder is elaborately mixed, formed into cakes under great pressure, broken into fragments, and rolled on belts till the fragments are polished. These fragments or grains are then sorted according to size and used for the purpose for which their size best fits them. The processes of manufacture in 1800 are well described by de Toussard. The common procedure of to-day is likewise well described by Marshall in his "Explosives."

34. According to Marshall the present procedure involves the grinding or pulverizing of each of the three ingredients separately in ball mills, bronze balls being used. The materials are then sifted, mixed in proper proportions, and put into a wood combining cylinder with wood balls. Another form of combining or mixing cylinder is made of copper and has through its center a shaft carrying a number of arms. The cylinder rotates in one direction and the shaft and arms in the other. Five minutes' rotation serves to mix the ingredients thoroughly. The mixture is then sifted and transferred to an incorporating mill in lots of from 60 to 80 pounds. From 3 to 6 per cent of moisture is maintained by adding distilled water from time to time. A popular type of incorporating mill comprises a flat bed with a vertical post around which two very heavy rollers rotate, being supported in such a way that they can not quite touch the bed of the machine and therefore can not roll the mixture to a less than a certain thickness of film, and at the same time they can rise if either encounters a large mass or lump of the mixture. The powder is rolled in such a mill for from one-half hour for mining powder (density 1.57) to five hours for small rifle powder (density 1.8). Wherever the powder is not pressed after milling the time of milling is greater than in processes where pressing follows. Some processes involve pressing in a hydraulic press under a pressure of about 400 pounds per square inch. The powder is built up in layers in the press, each about three-fourths inch in thickness while unpressed, and separated by sheets of copper, bronze, or ebonite. A column of such layers is compressed for a period of from one to two hours until a density of about 1.7 is secured.

35. The cakes so secured are then broken up and passed through rough gun-metal rolls and a series of sieves. The small fragments or grains are then glazed by tumbling in wood drums for about 30 minutes, with perhaps the addition of a small amount of graphite. The powder is then dried by means of a stream of warm dry air and given a final polish by being tumbled in a canvas-lined drum or cylinder.

36. *Testing.*—The earliest tests of gunpowder were simply to feel it to ascertain whether it was moist and to burn a little to see if much

PLATE 1.



BALLISTIC PENDULUM.

residue remained. The first instruments known for the measuring of the strength of powder comprised a small cylinder having a heavy hinged lid. The lid was prevented from falling back by a ratchet, and the angle to which it would rise on the firing of a given weight of powder was the measure of its strength. The modern ballistic pendulum is not materially different though much refined. This comprises a horizontal cylinder suspended from a knife edge, closed at one end and having a finely fitted piston at the other, the end of which rests against a fixed rest and a small rider on a graduated arc, Plate 1. When the charge is fired the piston is forced out and the cylinder in the opposite direction. As the cylinder moves back it pushes along the small rider which remains at the end of the arc of motion and indicates from the graduated scale the power of the propellant.

SMOKELESS POWDER.

37. The importance of smokeless powder is often overlooked, even by those who are interested in the development of new types of artillery and small arms. When an improved type of gun is designed and constructed, it is naturally expected that a suitable propellant will be ready to meet its particular ballistic requirements. For example, it is decided to construct a new caliber .50 machine gun, with a bullet six times as heavy as the service caliber .30 bullet, and with a velocity such as to enable it to penetrate tank armor. The volume of the cartridge case which must hold the propelling charge is decided upon, and the powder manufacturer is expected to produce a powder which will meet these requirements and not produce pressure in the gun greater than that prescribed by the designers. Furthermore, the allowable variation in pressure and velocity are very small, in order that the greatest possible accuracy may be obtained; there must be a minimum of smoke visible by day and of flash visible by night in order that the position of the piece may not be revealed; the powder must be chemically stable to insure its keeping qualities, nonhydroscopic to insure ballistic stability, and must have a sufficiently low temperature of combustion so that it may not cause excessive erosion of the gun. A brief review of the history of the development of smokeless powder may be of interest as serving to show how it has been possible to meet such requirements.

38. From the date of the earliest records of the use of firearms up to the middle of the nineteenth century, a period of about 600 years, black powder stood alone as the universal propellant with practically no change in its composition. Schoenbein discovered in 1845 that when ordinary cotton was treated with a mixture of nitric and sulphuric acids a striking change occurred in the properties of the

cotton without any appreciable change in its physical appearance. It had been converted into a highly inflammable material which offered promise as a substitute for black powder in firearms.

39. This discovery started experimental work in various countries, and within a short time attempts to manufacture the so-called guncotton on a large scale were made in England and France. An explosion of the still unfinished factory at Faversham in 1847 stopped the English investigation and two explosions in France the following year had a like effect in that country. The German commission reported unfavorably, pronouncing guncotton unstable, of uncertain force, and too expensive.

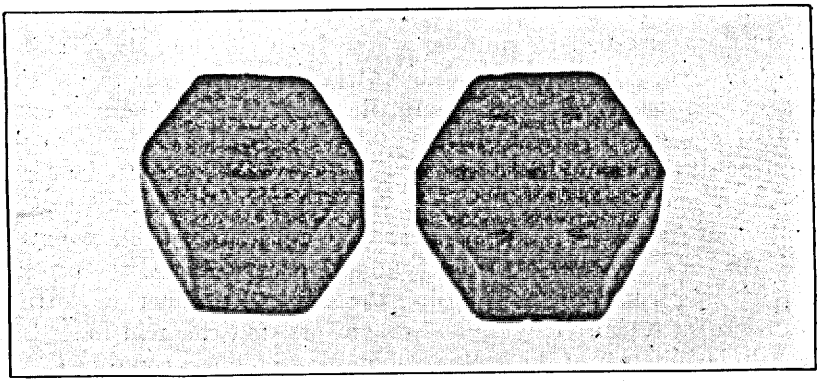
40. All investigations were discontinued except that of Von Lenk in Austria. He concluded that previous failures had been due to lack of stability resulting from incomplete purification, and his improved process included purification of the raw cotton by boiling in dilute caustic potash and washing and drying. His nitration product was washed in running water from three to six weeks in order to free it from excess acid. Attempts were made to use this improved guncotton in firearms in the form of loose fibers or spun into strings or cords, but the results were disastrous owing to the bursting of the barrels from the rapid rise of pressure. In 1862 and 1865 two magazine explosions in Austria, ascribed to spontaneous ignition of guncotton, stopped further manufacture in that country.

41. In 1864, however, Abel, in England, revolutionized the process of purifying guncotton by pulping the nitrated product, or cutting it up into such short lengths and fragments that the acid lodged in the cellular interior of the hollow tubular cotton fibers could be easily removed by washing. Abel's object in pulping his product was, however, widely different from the result obtained. He had hoped by compressing the pulped material into compact masses of uniform size and shape to control its speed of combustion and render it suitable for use in guns. Compression failed, however, to produce the desired result of regulating the rate of burning. Abel then went a step further by granulating his pulped guncotton by means of solvents, but although he patented this process he failed to carry it to practical success.

42. There was ample reason for the determined efforts that were being made to produce a satisfactory propellant from nitrocellulose. It burned with practically no smoke or residue and possessed about three times the energy of black powder. The improvements made in firearms at this time demanded a better propellant than black powder. Rapid-fire weapons could not give the best results without greater freedom from smoke and from residue in the bore. The reduction in caliber and increase in rifling necessary for greater range required powder of greater energy. Magazine small arms and machine and rapid-fire guns demanded a less bulky propellant than black powder.

43. Attempts to meet some of these requirements with black powder consisted in compressing it into larger grains of greater density and definite shape. The experiments conducted by General Rodman, of the Army Ordnance Department, in 1857 to 1869, resulted in the adoption of definite sized grains for each size of gun, some of which were perforated to give increased burning surface. These black powder grains were much larger than had been used, Plate 2, and the various types were styled "pebble," "mammoth," "perforated prismatic," and "perforated cylindrical." Further efforts were made to regulate the combustion of black powder by changes in its composition. For example, partially burned, brown charcoal was substituted for black charcoal, producing the brown prismatic or "cocoa" powder. This gave better results for large guns because larger charges could be used giving higher velocities without excessive pressures.

PLATE 2.



PERFORATED GRAINS OF BLACK OR BROWN POWDER.

44. It had been assumed that black powder burned under pressure in the gun in parallel concentric layers, just as it did in open air, except at a higher rate. Sarrau later showed this hypothesis to be in error. Vieille in 1884–85 also showed that even the brown prismatic powders were quickly disintegrated under the rapid rise in pressure, so that there was no longer any relation between the rate of burning and the original form of grain. He was the first to point out that gelatinized nitrocellulose burned with great regularity in parallel layers, even under the influence of sudden increase in pressure, thus indicating a means of definitely controlling the rate of combustion of propellants.

45. Somewhat prior to Vieille's work, however, Edward Schultze, a Prussian captain of infantry, invented a partly colloided smokeless powder made from a mixture of nitrated wood, nitrohydrocarbons, metallic nitrates, and sulphur granulated and superficially gelatinized by spraying with acetic ether. About the same time Reid and Johnson

in England patented E. C. powder, made in a similar manner from nitrocellulose pulp. These powders were particularly adapted for shotguns and small arms of low velocity. Their rate of burning was rapid and only partly controlled, rendering them unsatisfactory for use in rifles.

46. About 1886 Vieille placed the art of smokeless powder manufacture on a real foundation by producing the first thoroughly colloided nitrocellulose powder in the form of square flakes of uniform size and thickness. In 1889 Noble invented his "ballistite," composed of equal parts of nitroglycerin, capable of being rolled and cut in flake form. In the following year Abel and Dewar patented "cordite," a mixture of guncotton and nitroglycerin, colloided with acetone and containing a small amount of vaseline. This plastic mass was pressed through dies in the form of cords of suitable diameter.

47. In 1890 Mendeleef, in Russia, followed up the work of Vieille by pointing out a definite procedure by means of which a nitrocellulose of approximately uniform nitrogen content could invariably be obtained which produced a maximum gas volume on combustion and which, when thoroughly colloided with ether and alcohol in accordance with Vieille's procedure, could be graduated to form a satisfactory smokeless powder. He gave his nitrocellulose the name pyrocellulose, or "pyro" as it is called to-day. As early as 1893 Mendeleef's pyro powder was being manufactured on a large scale in Russia.

48. In the meantime a laboratory was established in the United States Navy. In 1893 Munroe patented for the United States a powder called "indurite," consisting of guncotton freed from lower nitrates by washing with methyl alcohol and colloided with nitrobenzene. The colloid was rolled into strips and dried or "indurated" by the action of steam or hot water, converting it into a hard, tough material. Following Munroe's resignation, in 1894, Lieut. John B. Bernadou, United States Navy, took up the work and in 1897 he patented a powder composed of uniformly nitrated nitrocellulose (about 12.45 per cent nitrogen) colloided with ether alcohol. This is substantially the service powder of the United States at the present time and is also identical with that produced by Mendeleef in Russia.

49. About 1893 Hudson Maxim and Robert Schupphaus developed a perforated black powder grain and the subsequent perforated prismatic cocoa powder. This type of grain was patented by Maxim in England in 1894. His powder was composed of 90 per cent of nitroglycerin and 1 per cent of urea, acetone being used as a solvent for the guncotton. This powder was much less erosive than previous nitroglycerin powders containing 50 per cent or more nitro-

glycerin, and the development of pressure was more sustained, since as the grains burned the size of the perforations increased, maintaining a more nearly constant burning surface. This type of powder was termed "progressive." It was made in grains and tubes of various lengths containing from 1 to 19 axial perforations symmetrically arranged. Further development of perforated powder grains was carried on by F. G. du Pont and others in the United States, and the American rights to the Maxim-Schupphaus powder were acquired by the Du Pont company.

50. Subsequent to the highly satisfactory tests of the Maxim-Schupphaus powder in various guns at Sandy Hook in 1895, this type of double-base powder was adopted by the Army, while the Navy adhered to the nitrocellulose single-base powder. This enabled a close comparison of the relative merits of the two types, and in about 1900 the single-base powder was adopted by the Army.

51. The use of double-base powder for small arms was continued, however, for a number of years, as difficulty was encountered in securing with nitrocellulose powder the desired regularity of burning at low pressure. In about 1909 the Army adopted a single-base .30-caliber powder developed by the Du Pont company, which contained a small amount of graphite added for the purpose of reducing temperature of combustion and lubricating the bore. In a service rifle this powder gave an accuracy life to 4,800 rounds, as compared with 1,500 rounds for double-base powder. This powder has a single perforated cylindrical grain, and is still in use.

52. The nitrocellulose cannon powder used by both the Army and the Navy of the United States was manufactured by the process originally patented by Bernadou, the American rights for which were sold by him to the Du Pont company. Briefly, the process of manufacture is as follows: Cotton, freed from oily materials and other impurities by boiling with dilute alkaline solution, followed by bleaching, washing, and drying, is nitrated by immersion in a mixture of nitric and sulphuric acids, converting it into nitrocellulose of the grade known as pyrocellulose or "pyro." This product is freed from the spent acid, first by centrifuging, then by washing and boiling with water, then pulped to reduce it to very short fibers. The pulp is further purified by final boilings and washings to remove the last traces of acid and unstable products, and is then separated from most of the water by centrifuging. It is then put in a dehydrating press, blocked, and alcohol forced through the block. The alcohol displaces the water and the block is left with a sufficient content of alcohol for the next process. The blocks are now broken up, ether added, and the mixture incorporated in a dough mixer. Upon subsequent compression in a press this mixture becomes a colloid or translucent, gelatine-like mass, which is finally

pressed through dies in the form of long, perforated strands, and cut by mechanical cutters into grains whose length is about two and one-half times their diameter. These are now subjected to a drying process, in the first stages of which a large part of the volatile solvent is recovered. During the drying the colloid hardens to a horn-like mass and undergoes considerable shrinkage. The dried grains still retain a small content of solvent varying from 1 per cent to 5 per cent, depending on the granulation. This residual solvent content must be kept constant by means of airtight containers in order to insure uniform ballistic results.

53. For a number of years smokeless powder for the United States Government was made almost entirely in private plants, the small Navy plant at the torpedo station being regarded only as an experimental project. In 1900, however, the Navy began the manufacture of smokeless powder on a large scale in its plant at Indianhead, Md., which was gradually enlarged in a few years to a capacity of about 10,000 pounds per day. In 1907 the Army completed a plant at Picatinny Arsenal, Dover, N. J., with a capacity of several thousand pounds per day. The manufacturer of even as little as 25 per cent of the peace-time requirement of powder in these two plants placed the Government in a position to thoroughly investigate the details of the process and stimulated similar action by private manufacturers. Improvements in the methods of purification and stabilization were made which improved the quality of the powder and greatly reduced its cost.

54. No matter how thoroughly purified, nitrocellulose has an inherent tendency to undergo a gradual decomposition, so that after a period of some years its ballistic qualities may have deteriorated to such an extent that the powder is no longer fit for service. To avoid the necessity for destroying such powders, a process of reworking was developed, whereby the powder was finely ground, reestablished, and made into new grains. This process has saved much deteriorated powder from destruction.

55. To counteract the tendency toward decomposition, various substances have been incorporated in the powder to serve as "stabilizers" by combining chemically with the gaseous "acid" products of decomposition as they are generated, thereby arresting decomposition in its incipiency. After exhaustive experiments, diphenylamine was adopted as the stabilizer in United States powder and is still used in an amount of about 0.4 per cent of the powder. Its use is claimed to have practically doubled the life of the powder. The 5 per cent of vaseline used in cordite exerts a similar influence.

56. An improvement in the drying process was developed in France which greatly reduced the time required for elimination of the solvent. By the air-drying method at 35° to 40° C. several

months were required for drying the larger sizes of grains. The new process accomplished this result in a relatively few days by immersing the powder in tanks of water, in which the solvent is soluble. When the water has absorbed the solvent it is drained off and the powder given a final drying in a circulation of warm air, which readily eliminates the remaining water. This process was largely used during the World War.

57. The Nash process of drying, devised by Mr. Nash, of the Hercules Powder Co., consists in immersion in alcohol for removal of the ether from the grains, then immersion in water for absorption of the alcohol. In less than 48 hours' treatment the powder is ready for the final air-drying for removal of the adhering water. This process was tried on a large scale with gratifying results, but has not been generally adopted.

58. Prior to the war much experimental work had been conducted in Germany to develop processes for the preparation of cellulose from wood pulp as a substitute for the cotton used in powder manufacture. The success of this work is indicated by the fact that practically all of Germany's war supply of smokeless powder was necessarily made from wood pulp, there being no available supply of cotton. Methods have also been developed in this country for the purification of wood cellulose and sufficient smokeless powder manufactured from such material to insure the practicability of its use in case of necessity.

59. It has always been found necessary to use an igniting charge of black powder with a propelling charge of smokeless powder, because of the difficulty of securing uniform ignition of the latter by the flash from the primer alone. Theoretically, every grain of powder in a charge should be ignited simultaneously and be completely burned at the same instant. In fixed ammunition an ignition charge of 21, 49, or 110 grains of black powder is combined with a percussion cap in the form of a "primer," but in separate loading ammunition, where the charge is made up in a number of bags, a larger ignition charge is necessary. This varies from 3 ounces to 6 pounds, depending on the size of the gun, and is at present used largely in the form of a single pad at the base of the rear section. Much experimental work has been done to determine the most suitable arrangement of the ignition charge. The "core" system, in which a small cylindrical core of black powder extends through the center of each bag, has many advocates, as has also the use of a separate pad at the base of each section. The latter system is the one used by the United States Navy, various forms of readily ignited fine-grained smokeless powder as an ignition charge have been proposed and tried out as a possible solution of the ignition problem. Much development work has been done and is still in progress to eliminate the muzzle

flash, which is visible at a great distance, especially at night, and serves to disclose the location of a battery. This flash is characteristic of both single and double base types of powder. This flash is due to the ignition of inflammable gases (carbon monoxide and hydrogen) as they issue from the muzzle at a high temperature and mix with the oxygen of the air. The addition to the charge of substances which lower the temperature of the gases or dilute them may result in preventing their ignition. Thus, the Germans added potassium chloride or common salt to the powder charge and the French incorporated a small percentage of vaseline or other carbonaceous material, with the result that some reduction of flash was obtained. Experiments made in this country have resulted in the development of powder for various field guns and howitzers which in night firings show only a small dark-red muzzle glow. Simultaneously with this development efforts have been made to reduce the tendency of the nitrocellulose powders to absorb moisture, a property which they possess to a greater degree than double-base powders. This work has been so successful that the Ordnance Department is hopeful of being able to produce a flashless, nonhydrogroscopic smokeless powder for practically all except larger caliber of guns, and even for the latter the problem is not regarded as impossible.

POWDER-CHARGE CONTAINERS.

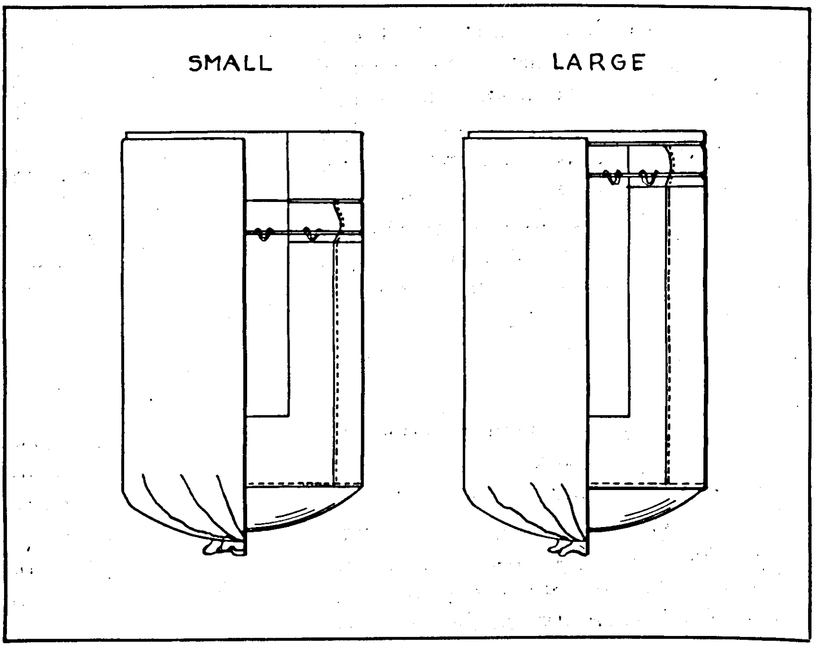
61. From the time of the earliest use of black powder in cannon in about 1250 to perhaps 1600, or ever later, it was the common practice to shovel the serpentine and corned powders into the cannon with a shovel or special scoop. As early as 1500 apparently there were attempts at the use of a container and the powder charge was occasionally put in a paper cartridge. It is not known why, but this practice apparently did not meet with universal favor. By the period of 1812 we find it the common practice to make up the powder charge in wool cloth or paper containers, as shown in Plate 3. Note the sabot included in the cartridge. Paper was the more commonly used for the heavy guns. This practice of handling the powder in paper containers continued until late in the century, when cloth was substituted. Even in our Civil War it was not uncommon to have the powder shoveled into the cannon, especially in the case of the large mortars.

62. *Metal cartridges.*—In 1866 a committee of the British Government selected a rifle presented by a Mr. Jacob Snyder, an American, as the best model for use in the British Army. At the suggestion of a Colonel Boxer, however, a metal cartridge was substituted for the thin paper cartridge. This is perhaps the forerunner of the

metal container that apparently has always been used in connection with our cannon of 3-inch caliber and less. Since the cartridge, powder charge, and the projectile of the 3-inch gun are of a total weight that can be handled at a satisfactory speed by one man, they have been assembled into a single unit by practically all countries. When made up in such units the ammunition is termed "fixed."

63. The earliest types of breech mechanisms used involved the use of a wedge. For reasons that all agree now are very good, the Germans have for a great number of years used the sliding-wedge type of breech mechanism that is commonly called the Krupp breech.

PLATE 3.



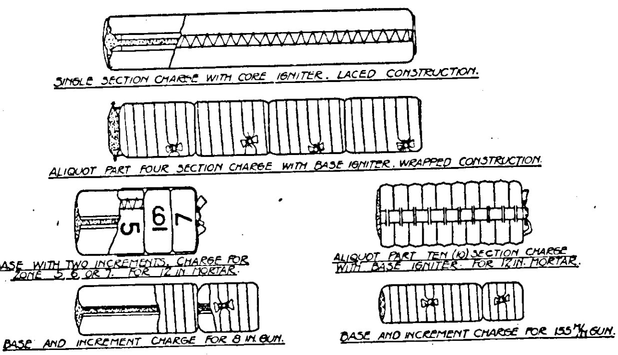
EARLY FORM OF CLOTH POWDER CONTAINERS.

With this type, and in fact with any wedge type, it is necessary to obtain proper obturation against the escape of the gases to the rear through the use of a metal powder container or at least a metal obturating cup. One finds therefore that metal containers or obturating cups are provided for all calibers of German guns and for guns in any country that have a similar breech mechanism. The brass cartridge cases used with the famous German 42-centimeter (17-inch) mortars look like metal tubs, and one can easily imagine the inconvenience of transporting and handling them. They have an advantage, however, in that since the primer is pressed into the center of the base and the front edge of the case wedges tightly into a

cone machined in the powder chamber, little or no difficulty is experienced with the firing mechanisms and correspondingly little difficulty is experienced with securing proper obturation. In fact, there seem to be such advantages in this system that General St. Clair de Ville, inspector general of the French Armies during the World War, recommended that it be adopted for use with French guns. It is doubtful whether we will ever make any such general change, although we found in our field service in 1918 that we were having great difficulties with the obturator pads used with the screw breech and correspondingly great difficulties with the separate primer and firing mechanism.

64. *Cloth containers.*—As soon as breech-loading cannon were adopted and put into general use in about 1860 the containers used for the powder charges received more attention than before. The method of making up charges began to receive much more attention

PLATE 4.



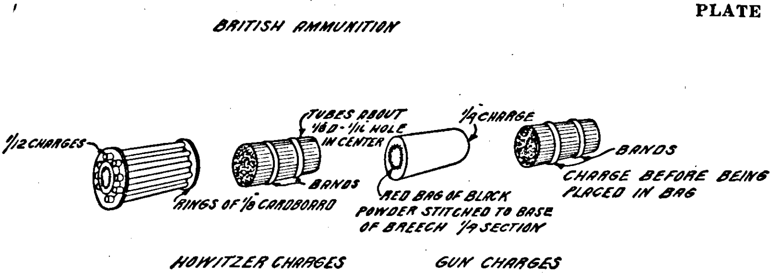
VARIOUS FORMS OF LARGE GUN CHARGES.

likewise. After considerable experimentation, silk has been decided upon as the best material that can be used as a powder container, principally because it seems to be more perfectly consumed on firing than any other material that will stand the handling that is necessary.

65. The silk cloth used for this purpose is, of course, very coarsely woven, resembling a fine weave of burlap, and raw silk is used, having the appearance of unbleached muslin. In our own artillery the igniting pads and cores of black powder are incorporated in or fastened to the sections of the charge, as shown in Plate 4. Since multiple charges are frequently desired, especially with howitzers and mortars, it is necessary to provide a means of quickly subtracting a fourth, fifth, or sixth, etc., of a charge. This also is shown in Plate 4. This reduction of charges is on the theory that no greater charge should be used than is required to reach the target in order that the wear on the gun may be reduced to a minimum.

66. *Celluloid.*—During the World War it seemed necessary to find a substitute for silk for powder bags, especially for use in the field. Not only was the demand for silk excessive, but there seemed a need for some material that would serve as a waterproof covering for powder in France, where the excessive moisture and continual drizzling rain made it very difficult to keep the powder charges perfectly dry. A celluloid envelope was developed, but was not put into service before the signing of the armistice. Such a material, if it

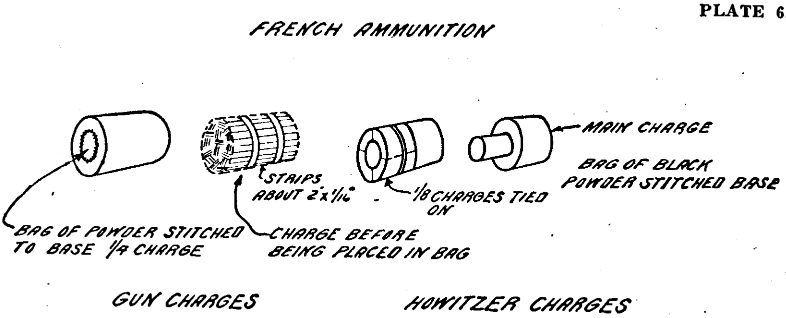
PLATE 5.



could be rendered sufficiently tough to stand reasonably rough handling, would be very desirable. It is possible, however, that such materials will be used only in those times when silk becomes difficult to procure or the field conditions are unusually severe.

67. *Multiple-charge containers.*—The use of multiple charges for howitzers and mortars has been mentioned under cloth containers. This does not apply so much to seacoast artillery as to the use of

PLATE 6.



heavy howitzers and mortars in the field. Since in the recent war the heaviest artillery in the field was manned by coast artillerymen, it may be of interest to mention here a scheme of making up multiple charges observed in the British Army. The British service uses the double-base powder cordite in the form of tubes about three-sixteenths of an inch in diameter. This form of powder made it possible to adopt a very convenient way of making up multiple charges, as shown in Plate 5. Each subdivision of the charges ob-

served was wrapped loosely in a bag made apparently of cotton flannel. These part charges were carried in a spool the core of which was a heavy fiber tube and the ends heavy fiber disks of a diameter to fit in the powder chamber. Each part charge was fastened to the end disks by a light cloth tape in such a way that a simple pull of the tape released it and it could be withdrawn from the spool and thrown away. A pad of black powder was fastened to one end of the spool.

68. In the French service, where the powder is in strip form, the part charges were simply tied in bundles like so many strips of cardboard and the smaller parts tied about the largest as a core, Plate 6, each separately, so that any single part could be removed without disturbing the remaining parts. In this case also a core of black powder is attached to the one end of the rear charge if it be very large or to one end of the bundle if it be in a single bundle. In some cases these bundles of strips are left uncovered and in other cases observed in the field the bundles were covered with cloth. In the case of their railway artillery the powder charges were transferred from the ammunition car to the gun in leather pouches to prevent too great a change in temperature as well as to protect it against moisture in damp weather.

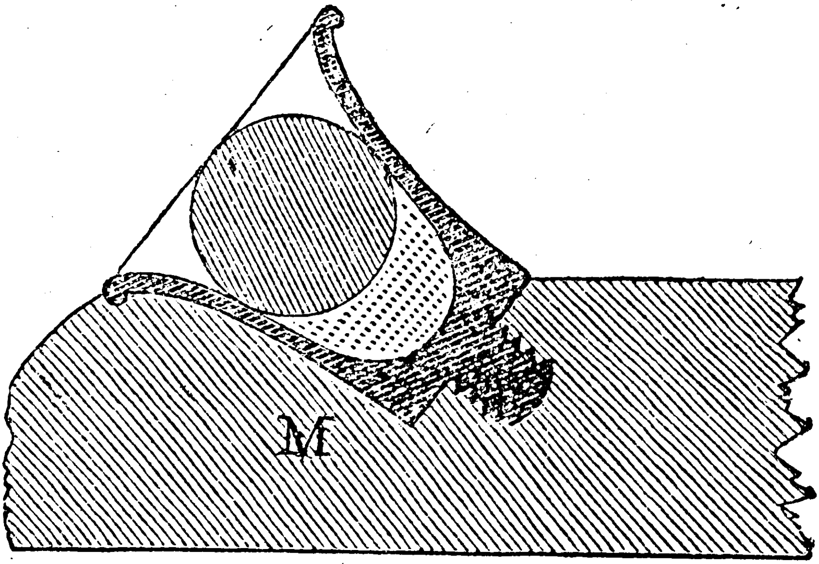
FUSES AND PRIMERS.

69. The first guns used from the approximate period of 1250 were of the crudest construction, used the crudest of projectiles, were served with the crudest of powder, and were ignited in a crude manner. It is difficult to determine whether the first guns were the shallow pots or mortars of the type shown in Plate 7, or whether they were made of rods of metal bound together into a tube. If the former, it is probable that the first method of igniting a charge was merely through a train of powder leading around the projectile to some point where it might be touched by a match of smouldering tinder or cloth bound to the end of a stick. In the case of the tube it is probable that the need of a vent was immediately seen and provided in some manner. Although iron was not then known in very great masses and was not melted in large masses, fine steel was known and drills of a sort were in use. Thus at a very early date the metal pots, mortars, and tubes were supplied with vents for the firing of the charge. Until 1850 at least, most cannon were fired simply by touching a light to the powder in the pan over the vent. Numerous difficulties were experienced and one wonders that some of these were tolerated since improvements are so obvious. For example, in the case of the great bombards, the cannon were frequently kept loaded for months. Great care was taken to keep the firing charge dry. In spite of all precautions, however, the charge would

frequently become moist and refuse to ignite. Further, the vents fouled badly with the earlier powders and had to be bored out.

70. *Reed tube fuse.*—Apparently the first type of fuse used for the firing of the crude earthenware shell invented in about 1450 was made by filling a hollow reed with serpentine powder. Since powder had been used for blasting purposes since at least 1200, fuses must certainly have been devised for that purpose. Paper was not then in use, but reed tubes were available, and since such tubes were used in the first earthen shell it seems likely that they were already known for blasting. To return to the priming and igniting of cannon charges, one finds that even the muzzle-loading cannon made and used in the nineteenth century still depended on the use of a train

PLATE 7.



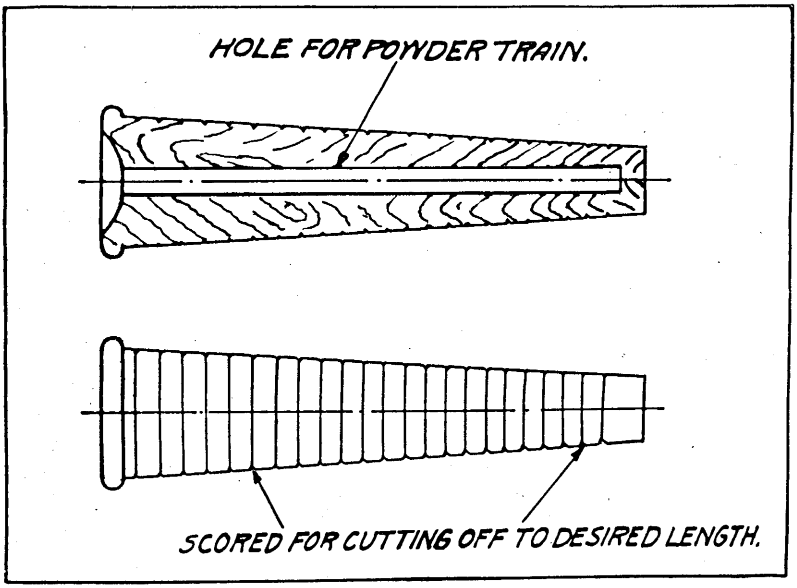
CRUDE VASE-SHAPED MORTAR IN PLANK FOUNDATION.

of powder in a vent and a further igniting charge in the pan cast in the cannon at the end of the vent. The curious part is that during at least the period 1450–1850 the same reed tubes and later paper tubes or even soft metal if desired might have been used, could have been introduced in the larger bombards whenever desired, would have eliminated the difficulty resulting from the wind blowing away the igniting charge, and would have prevented fouling of the vents. At this time the principal aim with the shell was to produce a fuse that would ignite the bursting charge, and the element of time was not so important. Later—that is, after 1674—when watches had been invented, it was possible to time fuses, and from that time it was possible to regulate approximately the time of the burst by

cutting the fuse to the proper length. In the middle of the eighteenth century fuses were made of wood tubes (Plate 8), beech wood being the principal wood used. At the siege of Gibraltar in 1779 the lengths of such fuses were so nicely regulated as to cause the shell to burst over the heads of the Spanish working parties.

71. *Metal tube fuse.*—At the sieges of Wachtendonck and Bergen-op-Zoom in 1588 an Italian refugee in the employ of the Dutch introduced the use of metal tube fuses in connection with metal shell. This tube was filled with a slow-burning powder, and the burning periods of the fuses were from 14 to 20 seconds, corresponding to ranges of from 1,000 to 2,000 yards with the mortars

PLATE 8.



EARLY TYPE OF WOODEN FUSE FOR SHELLS.

from which shell were at that time always fired. These metal tubes were driven into the fuse hole of the shell and were probably supplied in graduated lengths and driven into the shell on the field on approximate determination of the range. Fuses such as these were in use till after our Civil War. The shell fired from the very popular 13-inch mortars throughout that war were equipped with both metal and string fuses. The string fuses could be introduced before sending to the field and cut to the desired length there. At the present time the only survivor of the long-used reed, wood tube, metal tube, and flexible tube fuses is the black powder train in the highly refined time fuses of shrapnel and certain high-explosive shell. No very satisfactory substitute for this combination

has yet been found. Clockwork fuses have been used and are used, but they do not seem as satisfactory as the powder-train type.

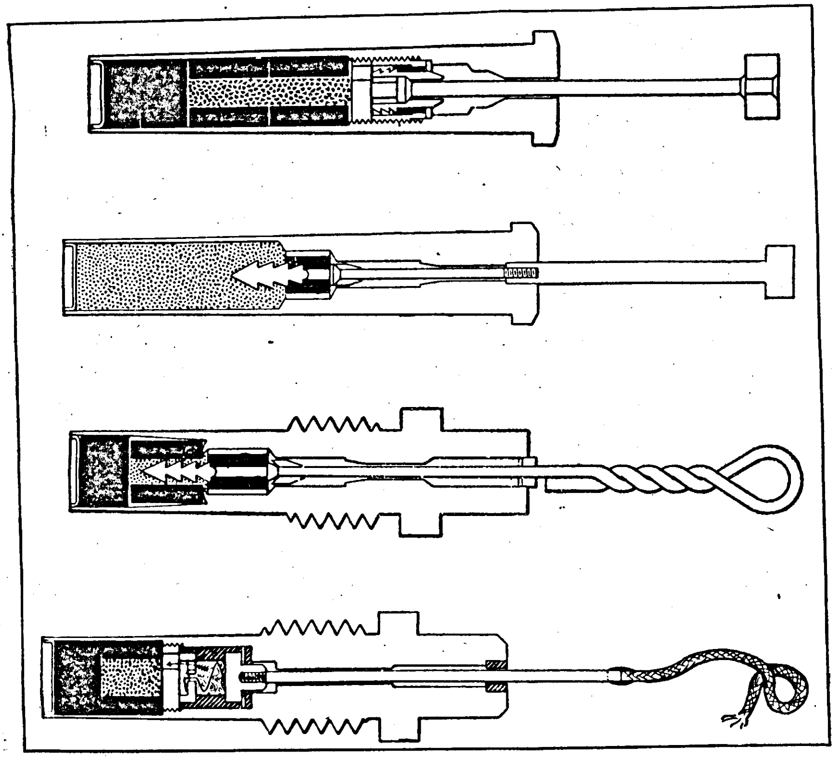
72. *Detonator primers.*—A Reverend Forsyth, who was acquainted with the detonating powers of potassium chlorate and likewise with the urgent need for a more satisfactory method of firing a gun or rifle charge than by means of a match, flint, or wheel lock, invented a detonator lock in 1805 which he applied to small arms, particularly sporting rifles. This device comprised a cylinder attached to the gun and in which was carried the detonating mixture of potassium chlorate, sulphur, and charcoal. On rotating this cylinder a small quantity of the mixture was fed into a chamber or hole leading to the vent. Another movement of rotation of the cylinder placed this small detonating charge in such position as to be under the hammer. The fall of the hammer then caused the mixture to detonate and fire the powder in the vent. It was thought for a time that this invention could be applied to artillery, and Forsyth spent considerable time in attempting an adaptation. He claimed to have succeeded, but his invention was not adopted, at least for any type of cannon.

73. *Fulminate cap and primer.*—The fulminates of gold and silver have probably been known since 1600. The credit for their discovery is generally given to a Cornelius Drebbel, a Dutchman. Neither was ever put to any practical use in artillery, however, because of the fact that they are so extremely sensitive as to make them dangerous of manufacture as well as use. During the seventeenth century these fulminates were frequently made by traveling entertainers and small quantities detonated for the amusement of the spectators, and it is not improbable that the knowledge of these led to the experiments which developed the fulminate which we now use. The fulminate of mercury was described in a paper presented before the Royal Society in England in 1800 by a Mr. Edward Howard. In 1814 an inventor by the name of J. Shaw, of Philadelphia, devised a steel cap or cup filled with fulminate of mercury which he used as a primer. In the next year he produced a pewter cap and in 1816 the copper cap that came to be used so generally and which was obtainable at most any hardware or sporting goods store even as late as 1906. It is possible that such caps can be procured even now for the few muzzle-loading small arms that one occasionally finds in use even at the present day. Such primers rapidly superseded the flintlock because of their obvious convenience and greater efficiency.

74. The development of the breech-loading small gun introduced a requirement which led to certain modifications in the primer as developed in 1814. It was desired to incorporate into one unit the shot, powder, and primer or cap. This merely called for a modi-

fication of the cup cap or primer, but, of course, difficulties were experienced before it was successfully developed. In 1836 a pin-fire breech-loading shotgun was introduced in France, and in 1841 the needle gun was adopted as the infantry weapon by the Prussians. In each case the primer was placed in the middle of the base of the cartridge. The needle gun used a cartridge, however, in which the base was solid, and the disk of fulminate was placed on the inside. It was necessary then to drive the needle through the base of the car-

PLATE 9.



FRICTION AND ELECTRICAL PRIMER TYPES.

tridge into the fulminate. This was not a successful scheme, because the gas escaped to the rear and fouled the needle as well as endangered the eyes of the user. The development necessary to perfect these small weapons, however, made it readily possible to construct the necessary cartridgelike primers for breech-loading cannon, which came into use rather generally in 1880. We say 1880 because in the Franco-Prussian War there were still in use great numbers of muzzle-loading cannon, and a large percentage of the cannon on our ships and in our forts were likewise muzzle-loaders, even though we had been constructing breech-loading cannon for at least 40 years previous to that date.

21 SECOND COMBINATION FUZE MODEL OF 1907 M.

FIG. 1.

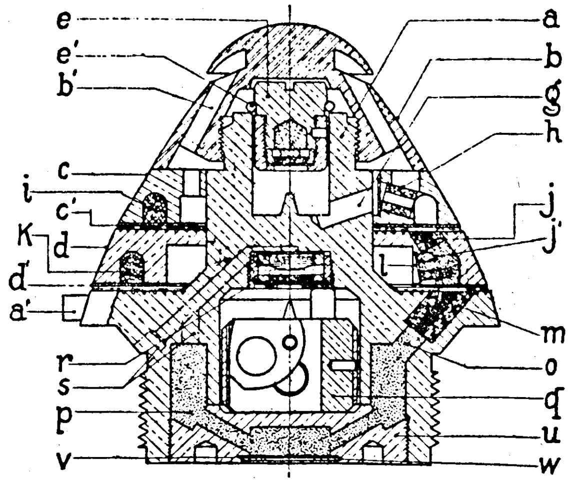
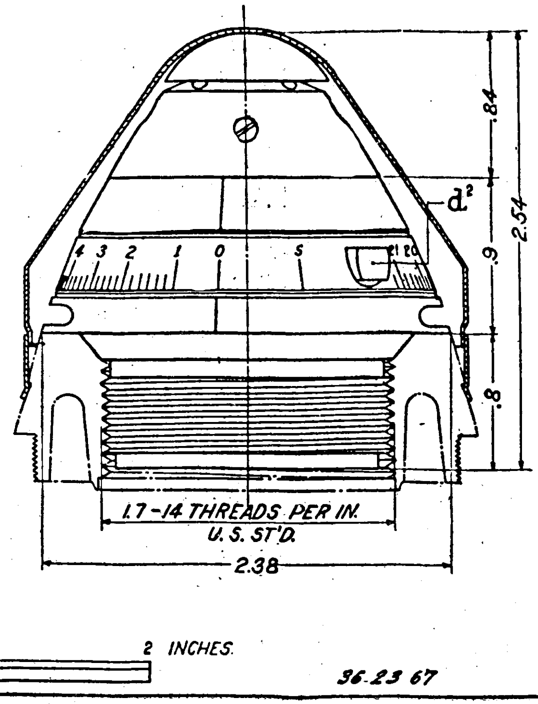
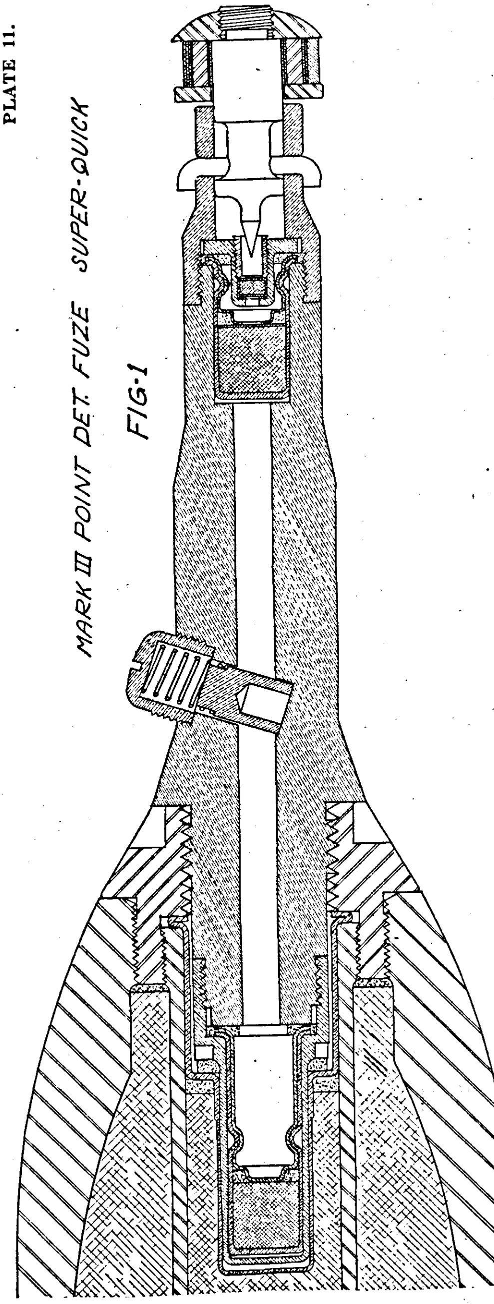


FIG. 2.



75. The primers that we know to-day are not essentially different from those of 30 years ago. Three varieties are in use—friction, percussion, and electric, Plate 9, and these variations have been made possible by the fact that fulminate of mercury will detonate from a blow, from friction, and from heat. Percussion primers have the advantage of avoiding the escape of gases to the rear and do not require the electric firing mechanism. It has not been so easy, however, to develop perfectly satisfactory mechanical firing mechanisms, and many of those used by us during the World War were not by any means satisfactory. The fire from the primer fouls the vent, and unless the operators are careful the obturating cone in the spindle becomes so fouled as to make it difficult to turn the primer holder up to the locking point, and a premature firing may result. If the cone is cleaned carelessly it may be so enlarged as to prevent obturation; the result is then a back fire. We see, therefore, that primers are not yet perfect. Less difficulty is experienced with those which are pressed into the bases of the metal cartridge cases, such as are used with fixed ammunition, or as with all German guns which have wedge breechblocks.

PLATE 11.



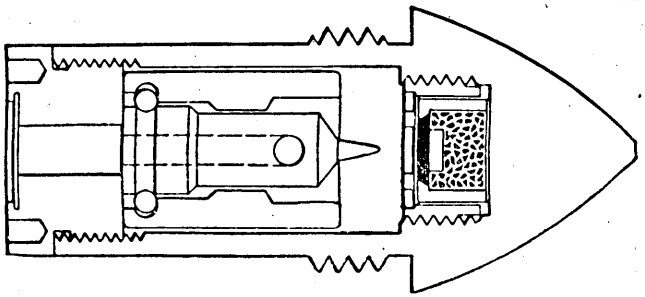
MARK III POINT DET. FUZE SUPER-QUICK

FIG-1

FUSE OF THE SUPER-QUICK POINT DETONATING TYPE.

76. *Percussion and concussion fuses.*—In 1846 the original of our present percussion time fuse was invented by an English quarter-

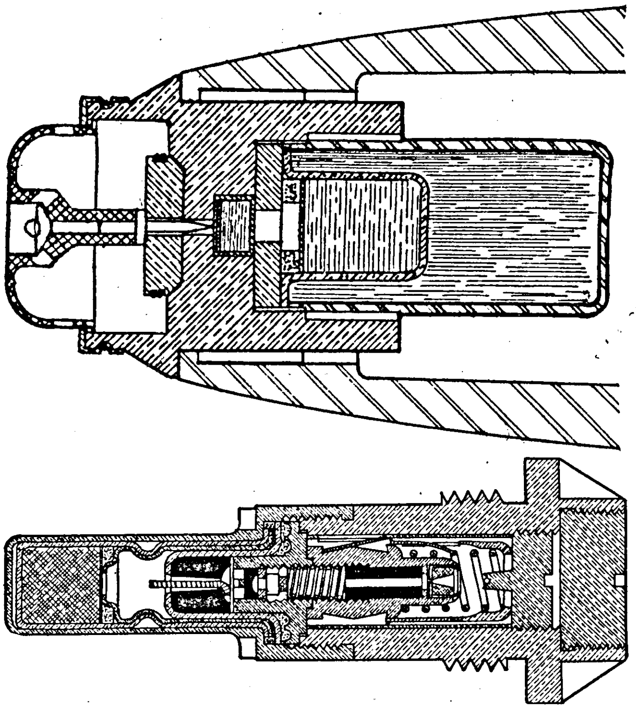
PLATE 12.



PERCUSSION FUSE WITH PIN ARMED FOR FIRING.

master, Freeburn. This fuse, as those used to-day, Plate 10, depended upon the inertia of a free cylinder of metal, pointed at the rear end,

PLATE 12A.



SUPER-SENSITIVE AND DELAY-ACTION FUSES.

sliding in an axial hole in the fuse proper. While at rest this hammer is kept forward by a light spring. When the gun is fired the projec-

tile moves forward, while the hammer tends to remain at rest until it strikes the pellet of fulminate at the other end of the axial hole. The detonation of this pellet starts the burning of the train of powder, the length of which can be regulated to correspond to the range.

76. The concussion fuse, Plates 11 and 12, acts or is supposed to act only on the sudden stopping of the projectile. In this case the hammer is to the rear and the pellet of fulminate forward. As the projectile starts a locking pin sliding in a hole radial to the axis of the proejctile is slung out by centrifugal force resulting from the rotation of the projectile. This locking pin is still out of the way when the projectile suddenly stops, thereby permitting the hammer to continue moving forward till it strikes and detonates the pellet of cap. The essential principles involved in the construction of both percussion and concussion fuses are the same now as when they were first devised. We are using different explosives and incorporate with the primary detonating mechanism such adjuncts as boosters composed of small charges of an explosive which is a little more sensitive than the main charge, but this may be considered an adjunct in the matter of power. Supersensitive and delay shell fuses, Plate 12A, are likewise merely the fundamental fuse with minor modifications.

HIGH EXPLOSIVES.

77. *Classification.*—It has already been mentioned that explosives burn or detonate at rates varying from 200 to 7,000 meters per second when formed into a column approximately 1.25 inches in diameter and at a density of approximately 1.45. It may be necessary to confine this column in a tube in the case of some explosives. Explosives detonating at rates of 2,000 meters or more per second are generally classed as high explosives. In this class are the following, with their rates of detonation. There are many other explosives, of course, but since they are not in common use in connection with artillery they are omitted.

Table of high explosives.

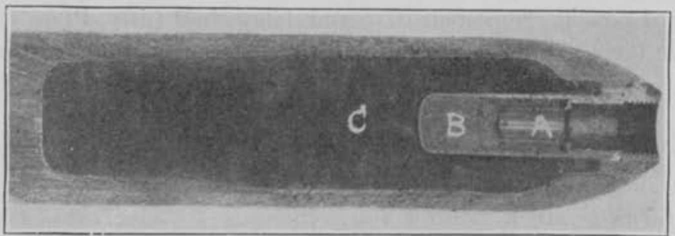
Explosive.	Rate of detonation (meters per second).
Fulminate of mercury	3,900
Ammonium picrate (Explosive "D")	5,500
Trinitrotoluene (T. N. T.; trotyl)	6,000
Trinitrophenol (picric acid; melinite; lyddite)	7,000
Trinitrophenylmethylnitramine (tetryl)	7,000

In connection with artillery, high explosives are divided into the three main classes: (1) Initiators—mercury fulminate; (2) boosters—tetryl; and (3) bursting charges—T. N. T., picric acid, and Explosive "D." The relation of these to each other is seen in

Plate 13. The properties of explosives that are of prime importance are: Power, sensitiveness, velocity of explosion, stability, and temperature of explosion. The last property is one that is of greater moment in low explosives than in high.

78. *Fulminate of mercury.*—This explosive has already been discussed quite fully (pars. 73–74). It has not been practicable to use it for any purpose in artillery other than as an initiator. It is an explosive for which one must have unceasing regard and respect. It is only safe when used in such small quantities as to barely make a noise on detonation. Since one seldom has occasion to use it in such minute quantities, the inference is that we must always be careful of it, whether in the caps of small-arms cartridges, in primers, or in projectile fuses. It is quite simple of manufacture, being made by first dissolving mercury in nitric acid, then pouring this combination into grain alcohol. Gray crystals of mercury fulminate settle out which are removed and washed. A microphotograph of these crystals is shown in Plate 14.

PLATE 13.

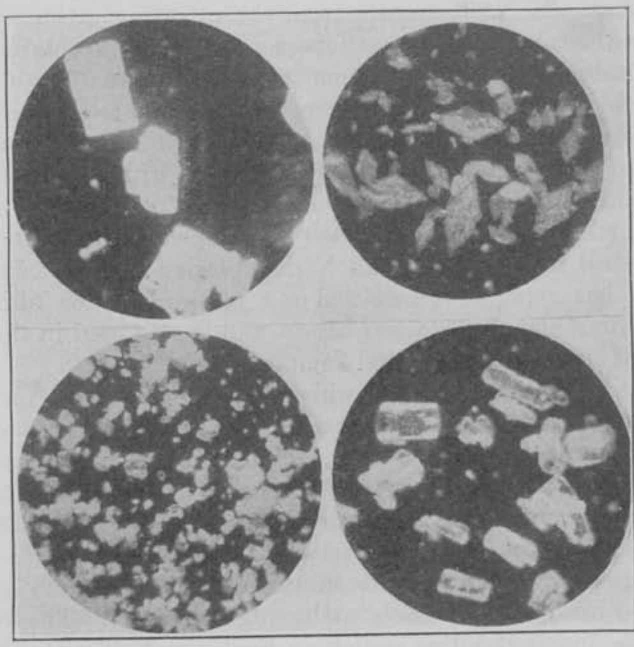


SECTIONED SHELL SHOWING FUSE AND BURSTING CHARGE.

79. *Picric acid.*—This explosive has been known since about 1771, at which time it was observed by the chemist Woulfe as the result of the action of nitric acid on silk. From that date until about 1871 it was known principally as a dye, although it was added to certain explosives as a combustion constituent. In 1871 the chemist Sprengel demonstrated that picric acid could be detonated by means of mercury fulminate. It was not until about 1885 that its advantages as a shell explosive were pointed out by Mr. E. Turpin, a French chemist, the advantages being its stability, insensitiveness, and violence. It was adopted by the French Government for use in shells under the name of melinite, and was in use by them as well as by the British, under the name of lyddite, at the beginning and during the early part of the World War. It is nearly as insensitive as black powder and for armor-piercing projectiles is quite a satisfactory explosive from this standpoint. It has the disadvantage, however, of forming more sensitive picrates if it comes into contact with metal and its melting point is rather high. At about 112°

C. it melts to a brownish oil. It was the practice in the American manufacture of picric acid high-explosive shell to pour the melted acid into the shell after the walls of the cavity had been coated with shellac or lacquer to prevent direct contact with the metal. The latest German practice was to pour it into vulcanized fiber containers of a shape to fit very snugly into the shell cavity. These charges could then be removed if desired and another charge substituted. This seems a better practice. Early in the World War the British Government found it necessary to discontinue the use of picric acid as their standard high explosive because of their inability to produce it in sufficiently large quantities.

PLATE 14.



MICROPHOTOGRAPHS OF EXPLOSIVE CRYSTALS.

80. *Ammonium picrate.*—This explosive, which goes also under the name of Explosive "D," is made by treating picric acid with ammonia. In the ratio of 54 parts to 46 parts of saltpeter, ammonium picrate was used by the chemist, Brugere, as a powder for the Chassepot rifle, which came into use in about 1865. It is as insensitive as picric acid itself, and having less tendency to form more sensitive compounds on contact with metals, it is considered superior for armor-piercing shell. The use of this explosive in American artillery began in about 1901. It melts at about 90° C. Even under the terrific shock that results from the impact of an armor-piercing projectile with 12-inch hardened armor plate this

explosive performs satisfactorily, and does not detonate until compelled to do so by the detonation of the booster charge of tetryl, which does not come about until after the projectile has passed through the armor.

81. *Trinitrotoluene*, *T. N. T.*, *trotyl*, *tritolo.*—This explosive was first made in about 1880 by the chemist Hepp, and in about 1891 its manufacture was taken up in Germany for use as a commercial explosive. It was taken under consideration by the German military authorities in about 1890, and in 1902 was adopted for filling shell and for other military uses. Italy adopted it in 1907, Russia shortly thereafter, and America in 1904. England apparently did not make any very great use of it until after the beginning of the World War. T. N. T. results from the nitrating action of mixed nitric and sulphuric acids on toluene. Toluene is obtained from the by-product of coke ovens, from the manufacture of artificial gas, and also by a special breaking-up process applied to oils, preferably of an asphaltic base. It resembles a light-brown sugar, has a specific gravity of 1.65, melts at about 80° C., is one of the most stable of high explosives, and does not ignite below a temperature of about 300°. A microphotograph of its crystals is shown in Plate 14. It is in general use for filling all high-explosive shells except armor piercing, has replaced guncotton and picric acid for filling submarine mines and torpedo war heads, and is also used in the manufacture of detonating fuse and composite detonators.

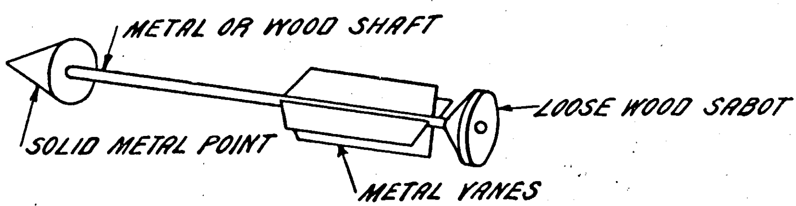
82. *Tetryl.*—This explosive, which has the unusually formidable name of trinitrophelymethylnitramine, was first made in about 1880. Its manufacture involves a very tedious process. Benzene is first treated with nitric acid to form nitrobenzene or oil of mirbane. This is reduced by iron filings and hydrochloric acid to give aniline. The aniline is mixed with sulphuric acid, wood alcohol, and a little iodine to serve as a catalyst or lubricator. This mixture is cooked in enamel-lined closed vessels under high pressure. The resultant product is dimethylaniline, which on final nitration with a mixture of strong nitric and sulphuric acid yields a substance which on drying resembles corn meal or yellow flour. A microphotograph of the crystals of tetryl is shown in Plate 14. It is a more powerful explosive than T. N. T., picric acid, or Explosive "D," as one would infer from its rate of detonation; but it is also somewhat more sensitive, without, however, being dangerously so with ordinary precautions. This combination of great power and slightly greater sensitiveness makes it suitable for an intermediate detonating agent. It is used in conjunction with fulminate as a filling for detonators and as a primer for high-explosive shell. Both the fulminate and the tetryl are protected against shock by the mechanical design of the fuse and the booster systems. In Plate 13 it is the booster

charge B. The melting point is about 127° C. It is somewhat poisonous and is liable to set up a skin irritation if handled too much. It has been in use in America as a booster explosive since about 1902.

PROJECTILES.

83. It is interesting to note that whenever we face a development in mechanical invention along a line that has been known in some form for a time, if suddenly diverted into a new channel by an unusual discovery, the development in the new channel follows or retains the characteristics of the old for a considerable time. Before the advent of gunpowder the missiles used by man in offensive and defensive warfare were arrows and stones. The evidence is that the first projectiles fired from tubes by means of gunpowder were arrows or javelins, the tips of which were frequently covered with some incendiary material. The next projectiles were stones, sometimes covered with incendiary materials, and stones con-

PLATE 15.



EARLY ARROW PROJECTILE.

tinued to be the standard projectile for several centuries. The interesting parallels to this development are in the first railway coaches which were in effect merely the conventional road coach on railway wheels, electric locomotives which first resembled steam locomotives, and automobiles which first were merely motorized conventional road vehicles.

84. *Arrows.*—In Plate 15 we see a type of arrow used from 1250 to at least 1300 as the conventional projectiles for such tube guns as were then in use. These arrows had metal feathers and points and were of a weight much greater than the arrows used in hand bows, but perhaps not heavier than those shot by the heavier engines. The counterpart of such missiles to-day is the rocket, which is projected from a tube of the order of a trench mortar, and the feathered cylindrical bomb used rather commonly in the World War. It is probable that we will always have some specialized branch of warfare in which this original projectile and gun will be reflected.

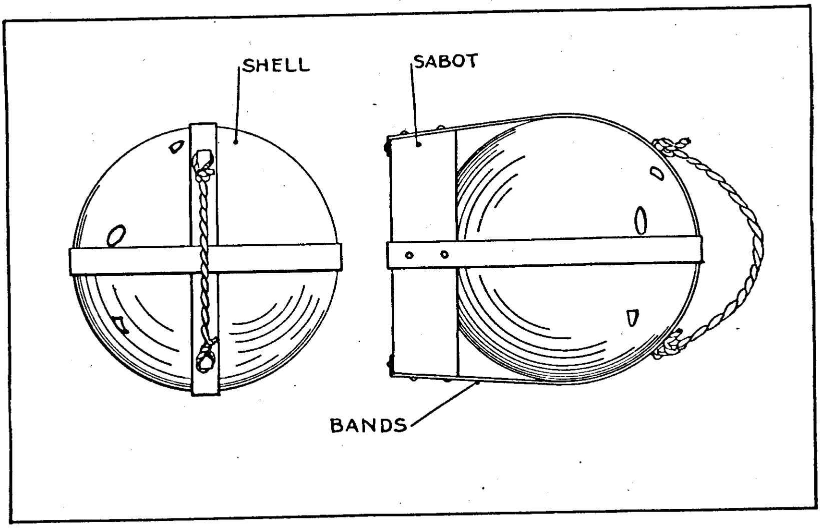
85. *Stones.*—The use of stones as projectiles continued at least until 1520; not because it was difficult at that time to cast metal into

the desired shape, but rather because there was not a sufficient supply of the various refined metals to permit their use in such quantities as were necessary in those days when a hit was the exception rather than the rule. Further, the first cannon of the various sizes, especially the mortars and cannon of the larger calibers, were used more in the destruction of such objects as could be crushed or crumbled by objects of great weight. The great bombards were trussed up to a certain elevation in front of a wall and left at that elevation until the desired breech had been made in the wall. In the case of the siege of Constantinople in 1807 the bombards were used by the Turks against the besieging ships, and the great stones did more damage in crashing timbers, jarring loose beams, crushing men, etc., than any small projectiles of metal could ever have done under the limits of accuracy and probability of hits possible at that time. There is a record to the effect that in 1469 stones were being used in connection with incendiary projectiles. Stones somewhat smaller than the bores of the guns were smeared with incendiary materials, pitch, sulphur, etc., and then wrapped with cloth soaked in similar materials. Such projectiles were used in the siege of Weissenburg in the year mentioned above—that is, 1469. The large stone projectiles used in the great 36-inch Russian gun, the 25-inch Mons Meg, and a similar 25-inch Turkish gun weighed as much as 2,200, 670, and 400 pounds, respectively. There is no record, apparently, to tell us to what degree of accuracy such stones were fashioned to approximate a sphere. Probably calipers were used to make certain that the greatest diameter did not exceed the bore of the gun, but it is not very probable that the "windage" or clearance ever was less than one-half inch.

86. *Cast solid projectiles.*—Solid shot came into use almost as soon as metal cannon of any description were made. They could not have been of cast iron, however, for assuming that cannon were made in 1250 it was nearly 100 years before the method of securing casting iron from the ore was discovered. Before then all iron as treated in the crude forges came out as wrought iron or as steel. For this reason the first metal guns were of wrought bars bound or welded together and the first mortars of bronze. The tin and copper necessary for the making of the bronze were not so plentiful any place as to permit very general use for projectiles. Early in the fourteenth century the methods of converting iron ore into free iron had been developed to the point of permitting the production of casting iron in at least small quantities and a few iron projectiles were made. There was not a sufficient supply of such iron available at that time to permit any very extensive use of it in heavy projectiles. It was not until the sixteenth century that cannon weighing as much as 3 tons were cast, partially because, as mentioned above, iron was not

available in sufficiently large quantities to permit its use in such heavy articles; and, further, furnaces had not yet been developed to the point of permitting the melting and handling of so great a weight of metal. It can be understood, then, that as long as guns were so crude and iron continued to be relatively scarce and rather difficult to work, stone projectiles continued in use. In the sixteenth century the equipment required for the production of casting iron had been developed to the point and production had reached such a scale that measures had to be taken in some countries to prevent the excessive use of wood from the forests for the necessary charcoal. Furnaces had increased in size, more improved blast machinery had been devised, and iron was becoming available in quantity at reason-

PLATE 16.



10-INCH COLUMBIAD SHOT WITH WOOD SABOT.

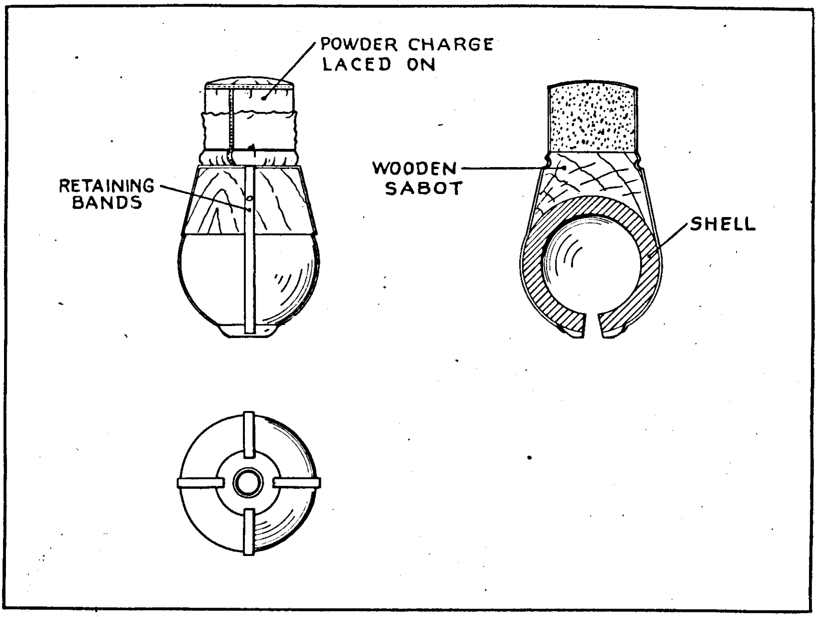
able costs. Round shot and shell continued to be used until the rifle supplanted the smoothbore cannon.

87. *Hot shot.*—It is probable that from the time that cast-iron shot were made it was realized that they would make an excellent incendiary projectile if heated red hot before being put into the gun. The mention of the use of hot shot is so frequent in the accounts of sieges and naval engagements prior to 1880 that one almost takes it for granted that its use began with the making of iron shot. The earliest record of the use of hot shot, however, gives the credit to Stephen Bathory, King of Poland, who in 1579 proposed the use of a thick, wet pad to prevent the hot shot from firing the charge prematurely. Hot shot have been especially effective against wood ships and against forts where there was a possibility of reaching the

powder magazine with them. The accounts of the bombardment of Fort Sumter in the first engagement of the Civil War mention the use by the Confederates of hot shot. In the siege of Gibraltar in 1782 the English used hot shot against the French ships to great effect. They filled shell with melted cast iron and quickly fired them. On striking, the shell burst and the red-hot iron scattered and fired the wood of the ships.

88. In the use of spherical shot, which, by the way, were used almost exclusively as late as the Crimean War of 1853, the Civil War of 1861–1865, and the Franco-Prussian War of 1870, there are numerous interesting adjuncts. In Plate 16 are shown spherical shot

PLATE 17.



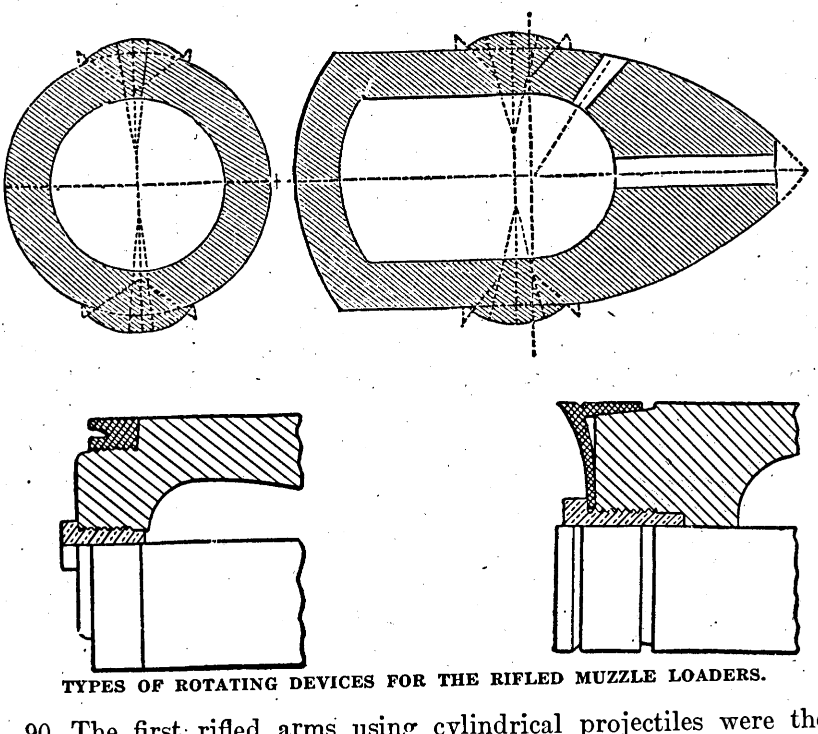
FIXED AMMUNITION FOR SMOOTH BORE GUNS.

with wood sabot either strapped with two thin metal straps or riveted fast. In Plate 17 the shot is shown with powder charge made up into a unit.

89. A cylindrical shot had been tried in smoothbore cannon, but it had been found that they tumbled as soon as they left the cannon and would not travel either as far or as accurately as the spherical shot. The scheme of producing rotation of the projectile by means of spiral grooves in the bore of the gun and the effect of such rotation on the travel of the projectile was apparently discovered accidentally in about 1520. From that date on we find numerous schemes tried and numerous variations in the design of the cylindri-

cal projectile were made in the search for the proper scheme, or perhaps more properly the design, to produce the desired rotation satisfactorily, and to check the escape of gasses past the projectile. Plate 18 illustrates some of the designs in the development from the first projectiles, fitted with lugs or covered with such a soft metal as lead, to the most modern projectiles, Plate 19, with a single copper band near the base for ordinary muzzle velocities (not exceeding 3,600 feet per second) and grooves and lands on the body of the projectile, Plate 20, for the higher velocities (3,600 to 5,500 feet per second).

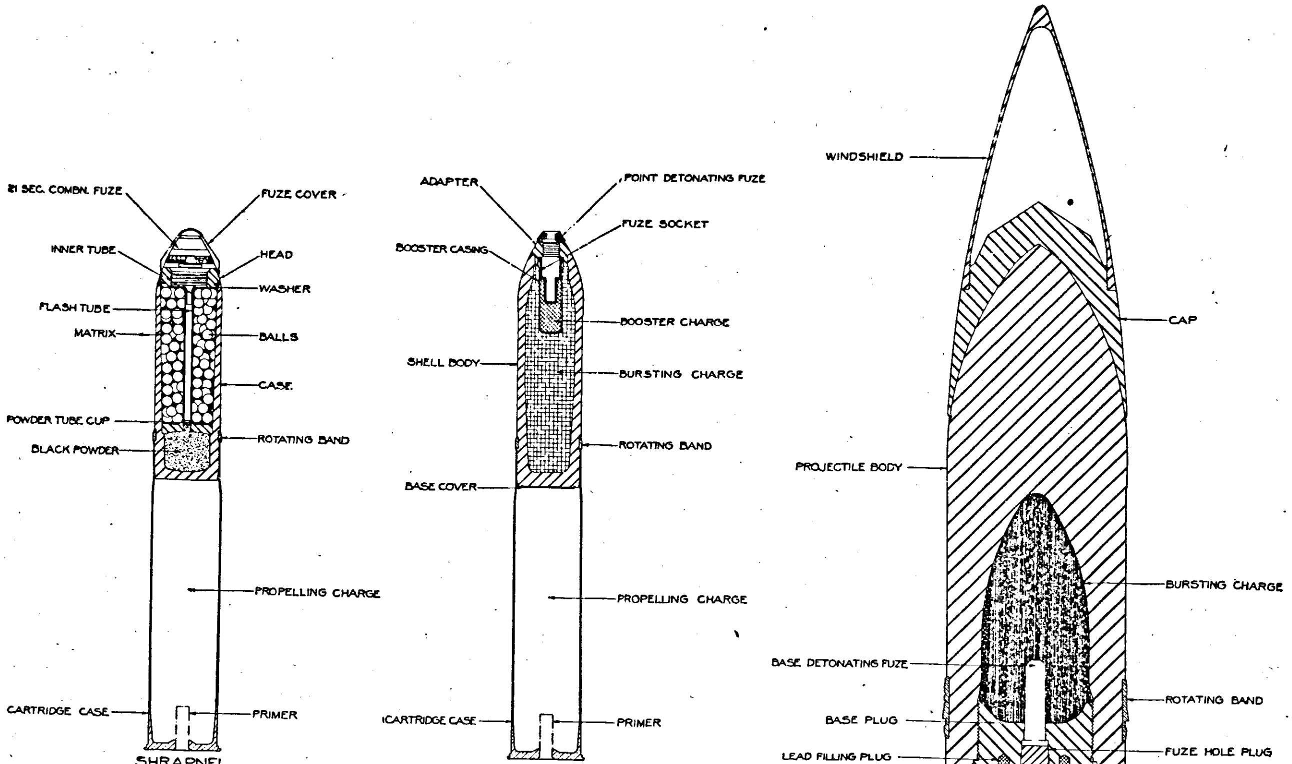
PLATE 18.



TYPES OF ROTATING DEVICES FOR THE RIFLED MUZZLE LOADERS.

90. The first rifled arms using cylindrical projectiles were the small hand rifle used for sporting purposes. These rifles were muzzle-loaders, and the necessity for ramming the bullet slowly down the barrel made loading rather laborious. If the bullet were rammed down too rapidly the lands produced on it might be sheared and the bullet would then get no rotation. The natural parallel in cannon was to coat cast-iron shot with lead and ram this in from the muzzle with a heavy ram. It can be realized easily what difficulties would be encountered in this procedure, and it is not surprising that it did not meet with favor. The next step with the small arms was to make a bullet, Plate 21, of such diameter as to drop down the bore without any resistance, but having a coned-out base with edges sufficiently

PLATE 19.



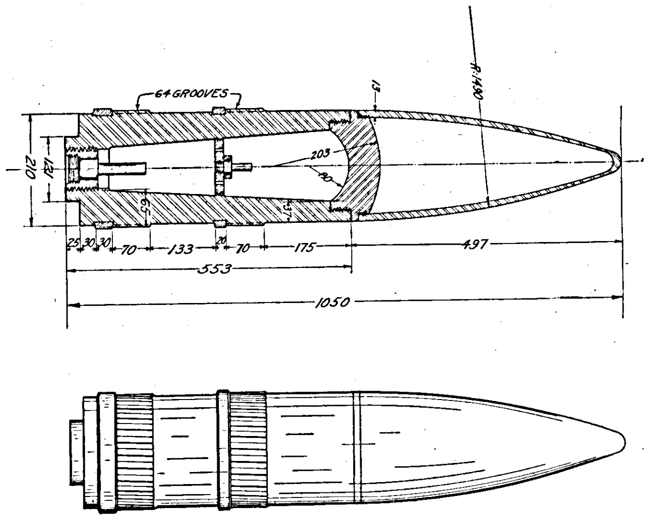
SHRAPNEL ASSEMBLED ROUND

HIGH EXPLOSIVE ASSEMBLED ROUND

ARMOR PIERCING PROJECTILE

thin as to be forced out into the grooves by the force of the powder gases on firing. This was not at all bad for small arms, and a similar

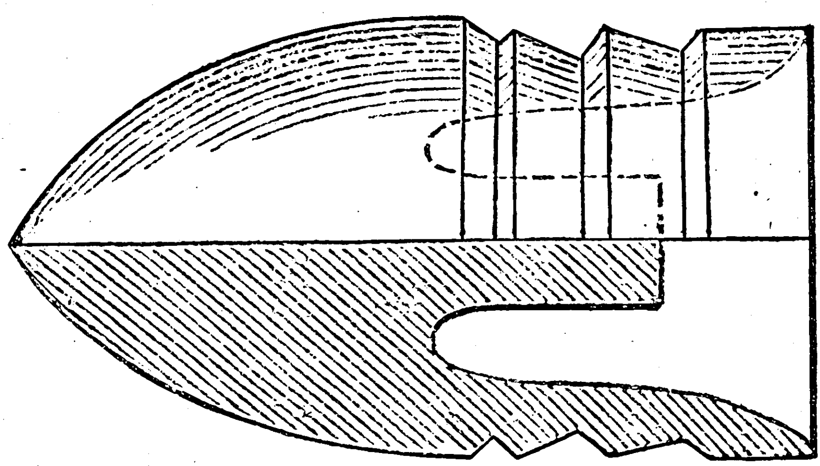
PLATE 20.



GERMAN LONG RANGE GUN PROJECTILE.

scheme, Plate 22, was tried with some success on cannon shot. The shot was cast with a rabbetted groove in the base, into which was cast a lead gas-check pad. The edges of this pad expanded into the

PLATE 21.

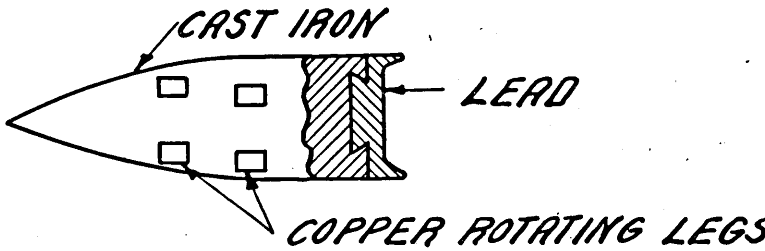


BULLET WITH BASE CONED OUT FOR EXPANDING.

grooves of the cannon on firing and produced the desired rotation. In Plate 23 another scheme of expanding soft metal into the grooves

on firing is illustrated. This involved a construction too elaborate to find favor beyond the experimental stage, and it would not be a satisfactory design in any but relatively crude rifles. As pressure was suddenly exerted on the base of the projectile the rear section was forced forward, wedging out the lead ring into the grooves. This scheme has the merit of continuing to force the metal into the

PLATE 22.

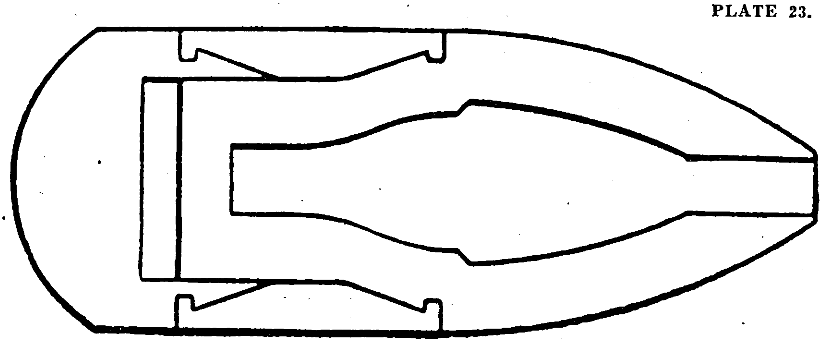


LEAD OBTURATING CUP ON BASE OF PROJECTILE.

grooves as long as the force of the powder gases continues to accelerate the projectile and produces a better seal against the escape of gases. It is known as the Hotchkiss design and was invented in 1865.

91. The next scheme tried with small arms is illustrated in Plate 24. Here the bullet is in two parts, the base section being composed of a disk of the diameter of the bullet with a truncated cone in

PLATE 23.



PROJECTILE WITH EXPANDING ROTATION BAND.

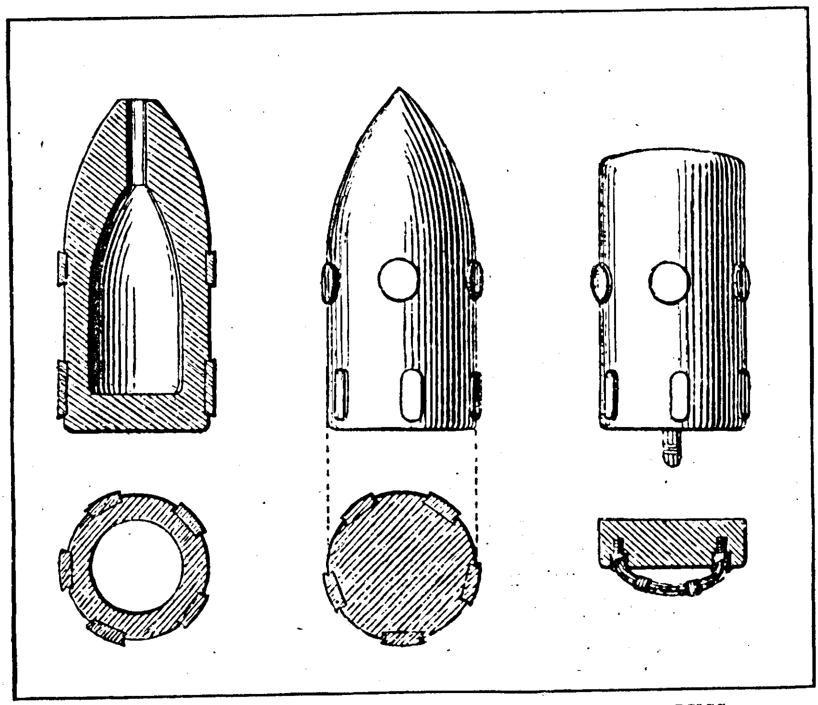
the center of it. This base cone was of such size as to fit only partially into the recess in the bullet proper. It was dropped into the rifle. The bullet was of such diameter as to slide down the bore of the rifle without ramming. After it had reached the powder wad it was rammed hard, thereby forcing the cone of the base up into the recess and the sides of the bullet out into the grooves. Bullets

of this description can still be found on the fields of various battles of the Civil War; this is especially true at Antietam and Gettysburg. In the period of the four years of the Civil War there were used round lead bullets with smoothbore muzzle-loading muskets. "Minié" base cone recessed lead bullets with muzzle-loading rifles, double expanding lead bullets with muzzle-loading rifles, and solid lead bullets with breech-loading rifles. There does not seem to be an exact parallel in cannon shot to the double expanding bullet shown in Plate 24.

PLATE 24.

92. For a time projectiles, particularly shell, were provided with two, three, four, six, or eight copper lugs set into recesses in the sides of the shell and arranged in one or two rings of two, three, or four each, Plate 25, depending on whether the gun, usually a muzzle-loader, had two, three, or four grooves. This scheme had the disadvantage of weakening the shell and required a reduction

PLATE 25.

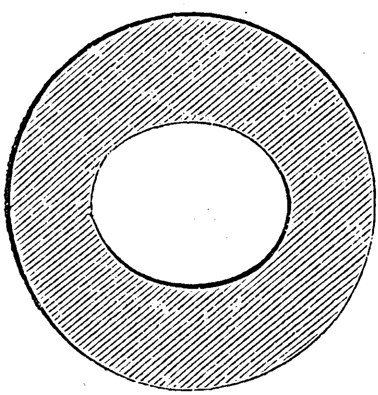


THREE TYPES OF SHELLS WITH INSERTED ROTATING LUGS.

of the cavity to withstand the stresses set up by the forces operating as the projectile traveled through the bore of the gun. In this scheme it was necessary to use either a soft metal base or copper disk on the base to secure proper obturation.

93. In addition to types of shot already described for the early rifled cannon there are two interesting designs that did not involve either copper or lead rings or lugs. These are illustrated in Plates 26 and 27. The design illustrated in Plate 26 comes first, apparently, having been designed in 1854, and a number of guns were altered to give it a trial in the Crimean campaign. A section of the bore of the cannon at any point showed an ellipse or oval, and the shot was a cylinder of corresponding oval section twisted to fit the bore of the gun. The guns modified to try out this design were of cast iron and of a quality typical of that time, hence most of them burst. Cast-iron cannon of that time could not be depended upon to stand very great pressures. They worked fairly well with spherical shot where the pressures remained relatively low, but with cylindrical shot provided with gas checks and rifled they invariably burst on comparatively few rounds. It is a sad commentary on those concerned that for many years rifled cannon were condemned for general use, because they so frequently burst in the trials. The judges were so stupid as to assume that the cannon were all right, and that rifling was all wrong, simply because it developed such pressures and stresses as to burst the guns. The oval section guns just mentioned really worked. They were difficult to machine, of course, and as we understand the art at this time we would not think of using such a design. One can nevertheless appreciate the merit of the idea. The other design, involving a bore of hexagonal section, was used by Mr. Whitworth in the various experiments conducted by him on both hand rifles and rifled cannon between 1855 and 1860. They were a success, and his results were excellent. He, too, had to contend with the cast-iron cannon, and frequently the success of his public demonstrations was completely overshadowed by the fact that the guns burst. In connection with this design of bore he and Sir William Armstrong were the first men apparently to do any really intelligent work in determining the proper twist for the rifling. Whitworth had constructed an inclosed range and tried small rifles of various degrees of twist

PLATE 26.

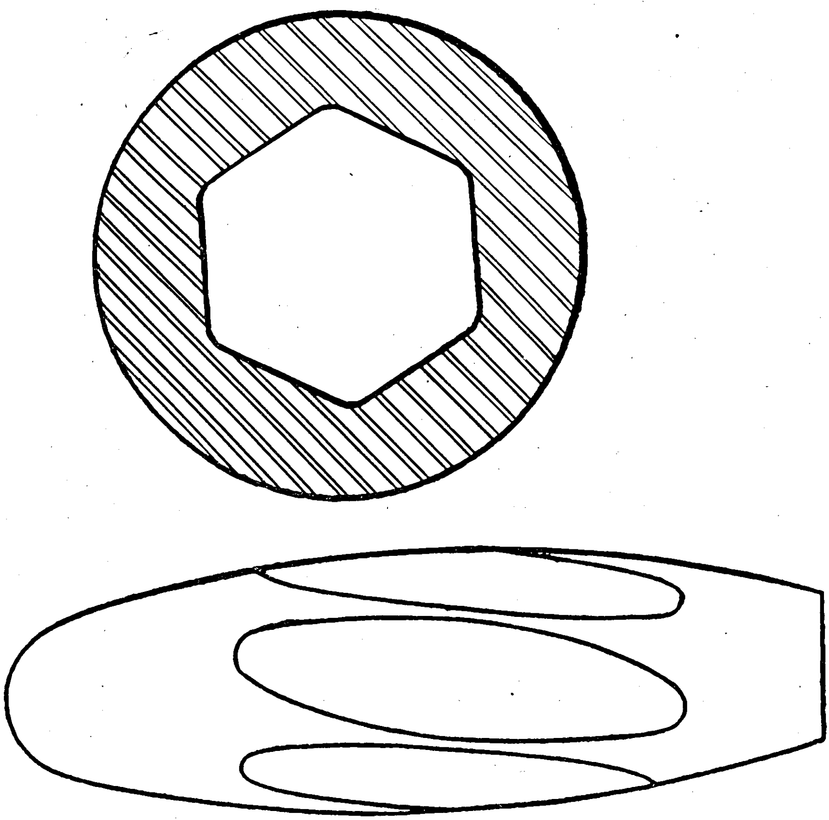


CROSS SECTION OF CANNON WITH ELIPTICAL BORE.

for the pressures and velocities that he could attain. The twisted hexagonal prismatic projectile can only be considered an incident in the general development, however, for it was never used to any considerable extent.

94. The work of Armstrong in the years 1850 to 1865 really developed the rifled cannon to the point where they put the smoothbore variety out of business forever. He saw that the first difficulty that had to be solved was in the material of the cannon itself. There was

PLATE 27.

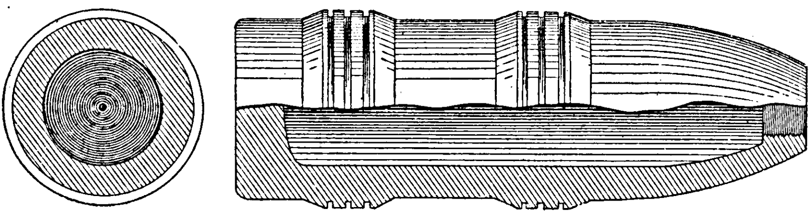


HEXAGONAL BORE GUN AND ITS PROJECTILE.

no use in trying to develop a principle with the aid of a machine that broke down every time one used it. He saw that if rifled guns developed pressures and stresses that cast iron could not stand there was no use in wasting time on the principle of rifling till the cannon could be made of better material. He therefore proceeded to develop the already understood scheme of building up a cannon by shrinking a series of hoops over a wrought-iron or steel tube. This procedure will be elaborated upon later. The result of his work,

however, was that he developed a saw-tooth grooved steel tube, built up a gun that was capable of standing the pressures developed, and then brought into use the forerunner of the projectile that we know to-day—that is, the cylinder of cast iron or steel with a band of soft metal about it which is forced into the grooves of the gun as it travels up the bore of the gun. These bands were sometimes double, one forward and one at the rear, Plate 28, sometimes single and near

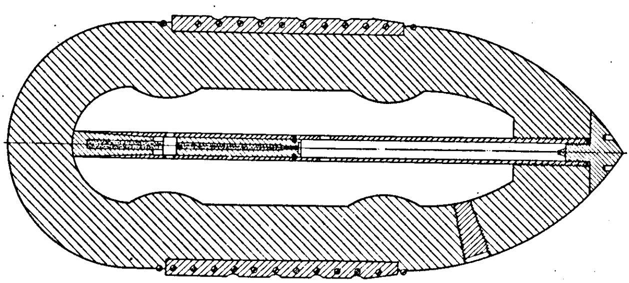
PLATE 28.



DOUBLE-BANDED PROJECTILE.

the middle of the shot, Plate 29, and later at the base, as we know it now. Since the period of about 1880 one can not say that there has been anything unusual in projectile developments until the beginning of the use of false caps, hard steel armor-piercing points, non-ricocheting points, etc., Plate 19. During the World War it was realized that considerable work might be done in the refinement of projectile design as to shape of the point, location of the center of gravity, and design of shape for various velocities and purposes.

PLATE 29.

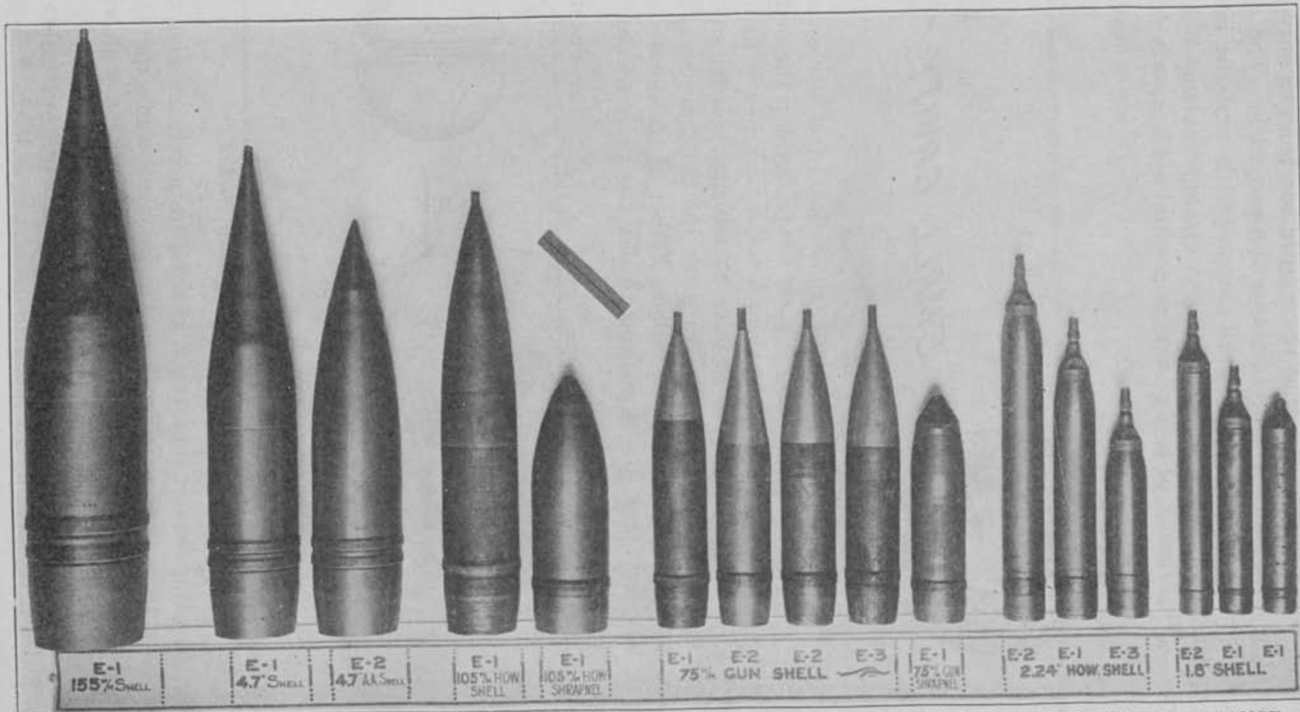


SINGLE BAND NEAR MIDDLE OF PROJECTILE.

A series of designs that have been under trial during the past two years is shown in Plate 30. Capt. R. H. Kent, of the Ordnance Department, is responsible for some excellent work in this refinement of design, and it is believed that through his efforts the design of projectiles has been advanced beyond the design of gun rifling.

95. *Rifled projectiles.*—The most spectacular example of a rifled projectile is the projectile used with the famous German long-range

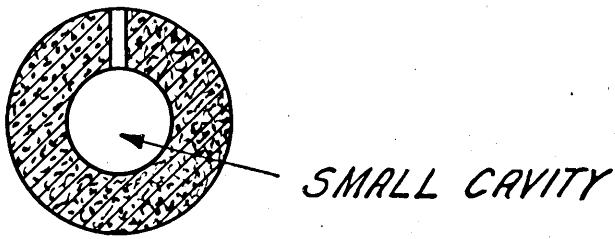
PLATE 30.



EXPERIMENTAL PROJECTILES OF VARIOUS SHAPES FOR REDUCING THE AIR RESISTANCE AND INCREASING THE RANGE.

gun in the bombardment of Paris from March 23 to August 9, 1918. The approximate design of this projectile is shown in Plate 20. It should be noted in this case that the copper bands serve only as gas checks, the steel lands serving to rotate the projectile. The erosion from friction between the lands of the projectile and the lands of the gun was so great that the guns were worn out in about 50 rounds thereby. This means, of course, that one would not use such a design

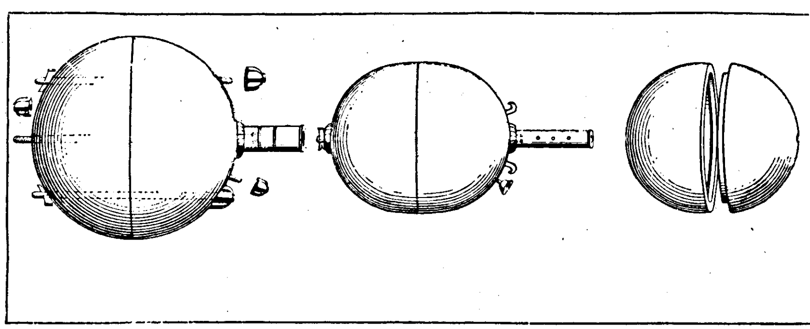
PLATE 31.



SPHERICAL CLAY SHELL.

except where the velocities are above about 3,600 feet per second in projectiles of small size, or where one wishes to develop the ordinary velocities of about 2,400 feet per second for a very heavy projectile in a short travel in the gun and under an unusual powder pressure. In either case the stresses tending to shear the band are so great as to make the copper band impracticable. Either of these cases are so unusual, however, that one is willing to pay the price of short life

PLATE 32.



TYPES OF FORGED WROUGHT IRON SHELLS.

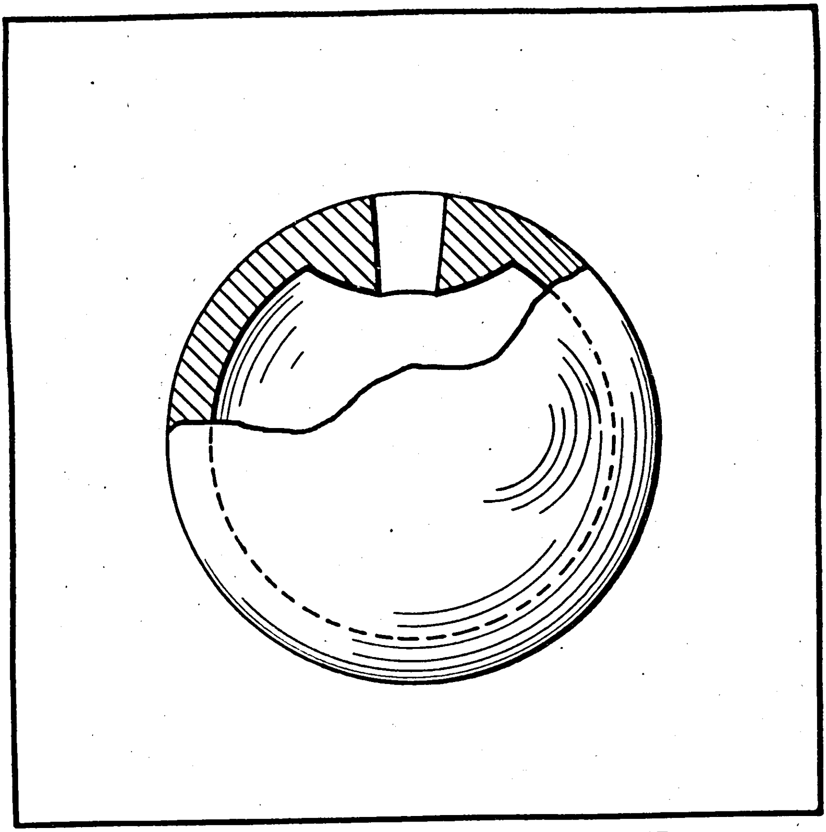
in order to attain some very much desired or necessary end. The Germans wanted a range of 72 miles. This required a muzzle velocity of about 5,200 feet per second, and the price was a very short life for a very expensive gun.

96. *Earthen shell.*—The first shell used during the fourteenth and fifteenth centuries were of a variety that must have limited their use very much. They were hard-burned hollow earthen or clay spheres, Plate 31, filled with an incendiary material and occasionally with

black powder. They must have been used principally for incendiary purposes, containing chiefly pitch, sulphur, and naphtha, with just enough of a charge of black powder to scatter the incendiary materials. When filled entirely with black powder the effect would largely be to terrify instead of to destroy.

97. *Forged wrought shell.*—Since the first iron available in quantity was wrought iron or a soft steel the only way in which shell could be made of iron was to forge two cups or hemispheres and

PLATE 33.



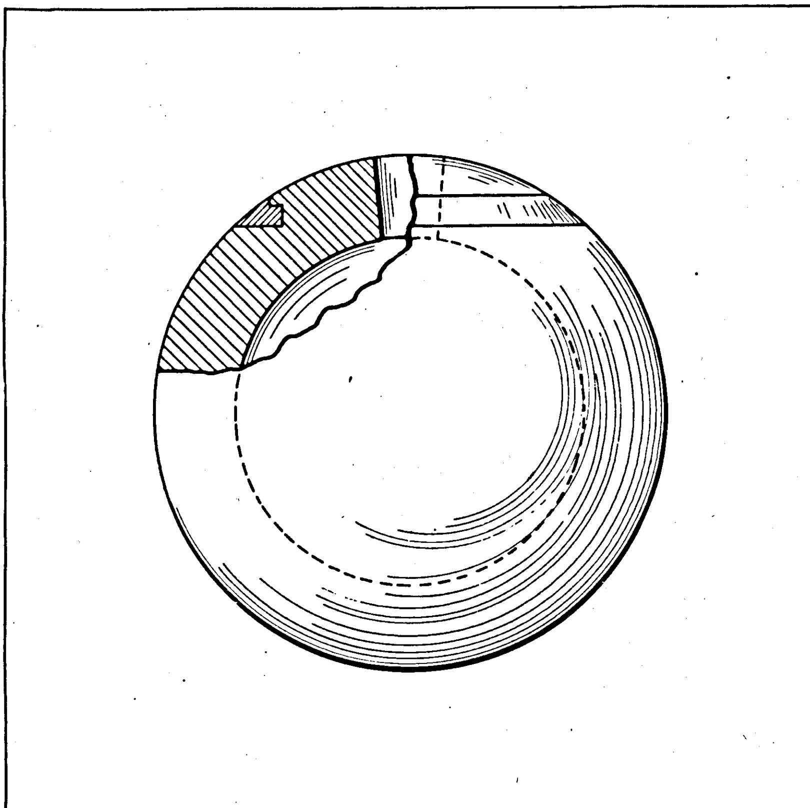
SHELL OF CAST IRON FOR WOOD OR WICK FUSE.

weld them together, Plate 32. These shells made during the fifteenth century were filled with a slow-burning powder well rammed in and provided with a fuse that was ignited by the fire of the cannon charge.

98. *Cast spherical shell.*—As soon as casting iron became available in the fifteenth century shell could be made of this material, and we find spherical cast-iron shell, Plate 33, used from then until after our Civil War. A great quantity of cast-iron shell cast during and after

the Civil War and stored in various places since were shipped to Watertown Arsenal even as late as the closing year of the World War, 1918 and 1919, to be melted and cast into something more modern. The 13-inch mortars used rather generally in the Civil War used a cast-iron shell weighing about 220 pounds and filled with black powder, Plate 34. As long as smoothbore cannon were used the projectiles were, of course, spherical, because the cylindrical projectile would tumble, since it had no motion of rotation. The

PLATE 34.



13-INCH SHELL FOR MUZZLE-LOADING MORTAR.

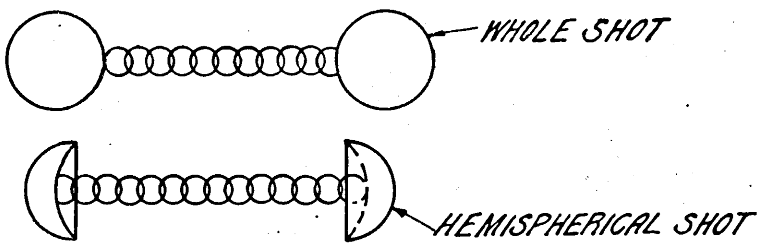
first Rodman guns, therefore, and even the large 15-inch gun cast under his direction in 1860 used spherical shell because they were smoothbore. The smoothbore cannon mentioned by Macklay as being still in use by the Navy in 1880 were used to fire chain and hot shot principally, and their existence at that time does not imply the use of spherical shell at so late a date in our service.

99. *Cylindrical shell.*—As soon as some of the Dahlgren and Rodman guns had been modified to the extent of the insertion of a rifled

wrought-iron tube in 1870 cylindrical shell made their appearance in our service. Cast-iron shell would be of no service now, but they were at that time, since most of the ships were still of wood. The first of these shell were provided with studs, as shown in Plate 25, and the guns were rifled with two and four grooves, respectively. These cast-iron shell were still filled with black powder, which charge, however, was fired by a concussion fuse instead of the crude type used with the spherical shell.

100. As soon as forging facilities were available to permit of the forging of masses of steel of a size to use for gun tubes and hoops, the multigrooved type of rifling could be used, and the shell were made of steel and provided with a copper band instead of the lugs. Such shell came into use in our service in about 1880. By 1890 the metallurgy of steels had been developed to the point of permitting us to make armor-piercing shell of a design shown in Plate 19 which were filled with picric acid. Since that time one can

PLATE 35.

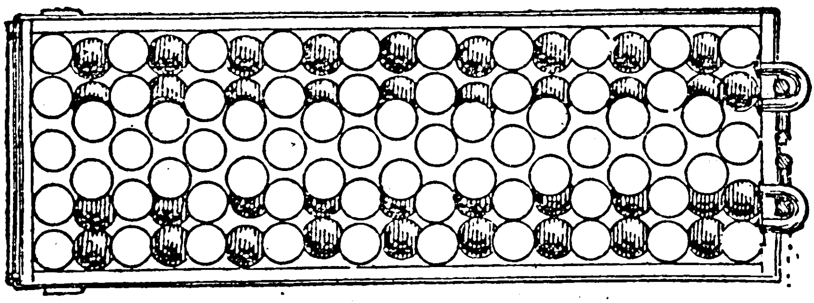


TYPES OF CHAIN SHOT.

not notice from examination of drawings of typical shells that we have made any great advance. There has been an advance, but it has been a refinement of the design and does not show so boldly in the drawings with which we must represent them. There has been a continual struggle between the designers and makers of armor-piercing projectiles and armor plate. For a time the manufacturer of armor plate merely continued to thicken his plate and improve its quality and composition, to the end of making it more difficult to pierce. When the weight of armor became so great as to be about at its limit, the designers of ships started to slope the sides of their ships in from the top down, thereby presenting an inclined surface to the projectile. The sides of the ships have been inclined at angles as great as 15°. During the past year tests have been conducted at Aberdeen Proving Ground in which 14-inch steel armor-piercing projectiles successfully pierced 14-inch armor plate on striking it at an angle of 25° from the perpendicular. This was an extremely severe test and numerous projectiles broke when par-

tially through the armor as a result of the terrific bending stress developed. Perhaps we are at the limit of this sort of development, at least temporarily, as the result of the work of the recent Limitation of Armament Conference.

PLATE 36.

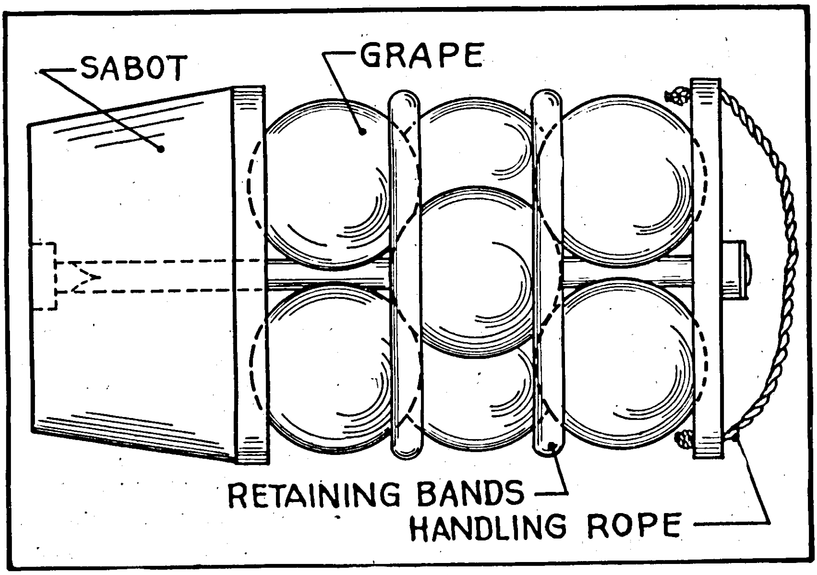


CASE OR CANISTER SHOT.

MULTIPLE SHOT.

101. *Chain shot.*—Chain shot, which consisted of two solid spherical shot connected by a chain or two solid hemispheres connected by a

PLATE 37.

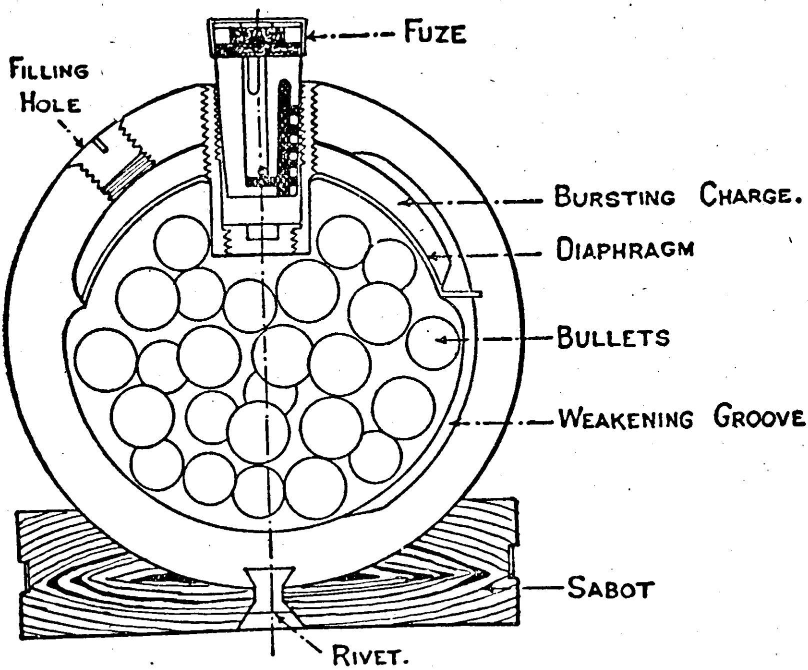


GRAPE SHOT.

chain, Plate 35, are said to have been invented by a Dutchman by the name of DeWitt in 1666. Such shot were used against the rigging of ships and continued in use as long as sailing vessels were used as men-of-war. This means at least as late as 1880.

102. *Case or canister shot and grape.*—Case or canister shot was used against troops at short range. It was first used in the early part of the fifteenth century and consisted then as since of a metal case or cylinder called a canister filled with small missiles of a weight at least equal to the average small rifle bullet, Plate 36, but greater in weight if desired. "Grape" shot implied larger balls arranged and held as in Plate 37 and were in general use in the Navy as well as in the Army. The metal case in which the small bullets or missiles were contained broke usually in the bore of the gun and the great number of missiles

PLATE 38.



SPHERICAL SHRAPNEL.

scattered like the shot from a shotgun. Such shot were usually reserved until the enemy had approached quite close to a battery, when fearful execution could be accomplished. One can easily imagine that some little courage was required to approach "to the mouth of the cannon," as one so frequently reads in the descriptions of numerous battles of the fifteenth to the nineteenth centuries, when the soldier knew quite well that there was probably a charge of canister shot awaiting his near approach. It equals the feat of taking a modern machine-gun nest. It was not uncommon to use large charges of small missiles loose, as in a shotgun, even as late as our Civil War. After a heavy wad had been rammed against the powder a shovelful of iron punchings or lead or iron bullets were thrown in and likewise wadded.

There was practically no difference between this and the canister inclosed shot.

103. *Shrapnel.*—Shrapnel shell were invented in about 1784 by a Lieutenant Schrapnel and it was intended to accomplish at long range what case shot would accomplish at short range. The first shell were spherical cast iron, Plate 38, and with a cavity that would permit only a small charge of black powder. This charge was intended merely to burst the shell and was purposely small because it was desired that the fragments continue to travel in the direction of the shell and with very little loss in velocity. They were officially adopted by the British Army in 1803. After the introduction and general adoption of rifle cannon, shrapnel shell gradually developed into the type that we know to-day, Plate 19. This consists of a shell having a charge of black powder in its base, a core of black powder reaching to the point time fuse, and the remainder of the space is filled with lead bullets about which rosin or some other relatively brittle substance is poured. When shrapnel shell were originally devised they were used in cannon larger than 3 inches. The standard shrapnel shell of all countries now is approximately of 3-inch caliber and comes under the head of "fixed" ammunition. All shrapnel shell are provided with time fuse, upon the accuracy of operation of which their efficiency depends. They are tremendously effective against troops in the open, but have little or no power against troops well intrenched or protected by adequate overhead shelter.

CANNON.

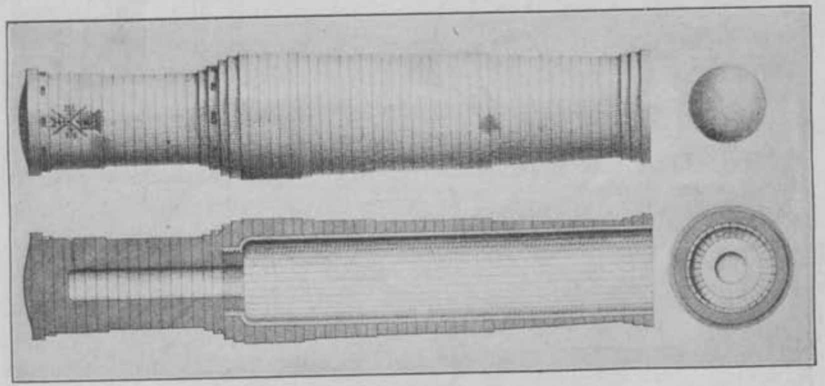
CANNON TUBES.

104. In the period from about 1250 to the present date cannon (L. canna, a tube) have been developed from a crude tube made by binding or welding together a number of wrought-iron rods, or from a crude pot cast of bronze or forged or wrought iron, Plate 7, to the mammoth cannon of to-day of which the limit of development is our recently finished 16-inch 50-caliber seacoast gun (O. N. Gunnilde, gunnethilde, war), Plate 159. To the best of our knowledge no other nation is using a gun that develops equal muzzle energy, so that from a nation that began its existence on an independent basis only 146 years ago we have developed to the point in the science of artillery where we are building and using the greatest weapons in existence, in spite of the fact that most of the development of which our weapons are the present limit began in countries of Europe before this country became an independent nation. The probable muzzle energy developed in the original gun or cannon of 1250 did not exceed 500 foot-pounds. The muzzle

energy of the 16-inch gun mentioned above is 8,500,000. This represents a 17,000 fold increase in powder.

105. In dealing with the development of cannon tubes one finds it convenient to divide the total span of years from 1250 to the present date into three periods. The first extends from 1250 to about 1520, during which time the projectiles were first arrows and later stones, the weight of which finally reached the formidable figure of 2,200 pounds and the diameter of the bore of the largest gun 36 inches. The second period extended from 1520 to about 1850, during which time smoothbore cannon continued in use, but the projectiles were spherical metal shot and shell instead of stones. During this period some progress was made in the casting of cannon of iron, but they were not very reliable, and when made heavy enough to stand the pressures they attained tremendous proportions, considering the

PLATE 39.



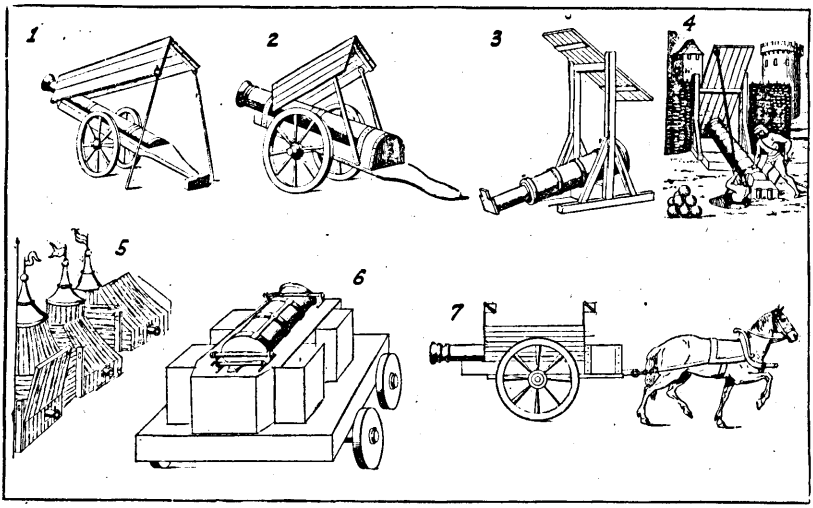
THE DULLE GRIETE OF GAUD.

weight of the projectile used in them and the range attained. Bronze cannon were much preferred because the metal was more homogeneous and more reliable. The third period began in 1850 and is still with us. This period began with the rather general acceptance of the necessity for rifling in cannon as well as in small arms, the use of elongated or cylindrical projectiles, the use of steel instead of cast or wrought iron, and the adoption of the built-up type of construction instead of a single-piece gun. The progress made during this short period is nothing less than remarkable and is a most striking contrast to that of the previous 450 years—that is, from 1400 to 1850. The period from 1300 to 1400 is in some respects nearly as remarkable, for from the crude pot or equally crude tubes used at the beginning of the fourteenth century the gunmaking craftsmen had progressed in 100 years to the point of making a wrought-iron gun, the Dulle Griete, of Gaud, Plate 39, weighing 13 tons, of a

built-up design, with a bore of 25 inches, and capable of firing a stone projectile weighing 700 pounds.

106. *Thirteenth century cannon.*—In Plate 40 the cannon of various descriptions made and used from 1250 to 1300 are shown. Some of these guns are of Arabic origin and some perhaps of Chinese, Indian, and Egyptian. It is interesting to observe the fantastic designs that prevailed for so many centuries. Some of these original guns were quite highly ornamented cast-metal pots; and, in the case of guns, it seems to have been a common desire or tendency of the cannon designers and founders to represent some animal or a dragon in the act of spitting flame, smoke, noise, and venom in the form of a missile. Guns cast even as late as 1750 show such fantastic designs. It is in-

PLATE 40.



THIRTEENTH CENTURY CANNON.

teresting to speculate how the knowledge of artillery spread so rapidly over almost the whole of Europe. In 1313 it seems that practically all countries were casting and using cannon. Some have given 1313 as the date of the earliest use of artillery. It would be obviously impossible, however, for the art to be discovered, developed, as it appears to have been in 1313, and spread over the whole of Europe and a large part of Asia in even a decade, at a time when the methods of travel and communication were so laborious. It would be simply impossible. The earliest English record of the use of cannon has the date of 1326 and describes a knight in armor firing a weapon shaped as a vase and loaded with an incendiary arrow. This weapon has a vent at the breech end where the match was applied. Some of the weapons shown in Plate 40 would seem to come under the heading of small arms rather than cannon. It is

doubtful, however, whether there was any such weapon as a hand gun until about 1350. There is a record in the Proceedings of the Royal Artillery Institute, England, Volume IV, page 291, to the effect that in 1338 there were both iron and brass cannon of small size and that some of these were breechloaders, for which 2 pounds of serpentine powder was allowed for 48 arrows. This would make a very small charge per arrow—about seven-eighths of an ounce. The guns would apparently be classed as small cannon, however. Such as these and the fantastic pots and crude tubes would constitute the accomplishment to 1300.

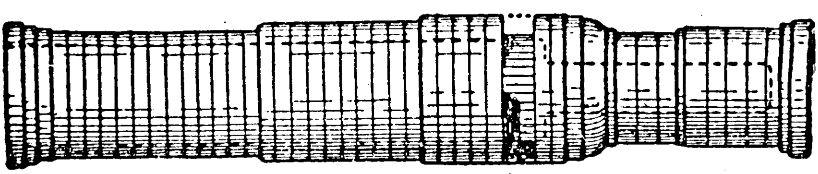
107. *Fourteenth century cannon.*—The beginning of the fourteenth century finds cannon as pots of brass and wrought iron, or tubes of relatively small weight and of the same materials. During this century remarkable progress was made. It is thought that the great Dulle Griet, which was used by the people of Ghent in 1411, was made in about 1382. This gun, Plate 39, weighs about 13 tons, has a total length of 197 inches, a diameter of bore of 25 inches, and a powder chamber tapering from 10 inches diameter to 6 inches, which is thought to be screwed to the muzzle portion. It fired a granite ball weighing about 700 pounds. The lining or inner tube of the gun is formed of a series of longitudinal wrought-iron bars welded together. This is surrounded and reinforced by a series of rings, likewise of wrought iron, and either driven or shrunk on. The existence of this type of construction at this early date should not be interpreted as indicating a recognition of the superiority of the multipiece or built-up gun over the one-piece or cast gun. They simply developed what might almost be termed a craze for large-caliber guns. They were able to make them of wrought iron by this method and proceeded to do so. Probably if they had been able to cast them of iron to such a size they would at least have tried it. It is certain that cast-iron guns of such size would have burst had they made them.

108. Two wrought-iron guns of about the same period of construction, the larger of which has a bore of 19 inches, were left by the British when they were compelled to raise their siege of St. Michel, in France, in 1423. "Mons Meg," the great wrought-iron gun which is at Edinburgh Castle is approximately of this period, at least in type of construction, though made a little later. This gun, Plate 41, has a caliber of 20 inches and fired a granite ball weighing 330 pounds. These huge guns were termed bombardes, from the special service for which they were used. They had a relatively short range, not more than several hundred yards, and it was the custom to truss them up to a certain elevation on a simple wood platform or cradle and let them stay at that elevation until the wall against which they were being served had been breeched.

Similar guns used in coast fortifications were trussed up to a fixed elevation and were served against ships coming under the forts by timing the firing to the position of the ship. They were so heavy as to be unadaptable to ready training in either elevation or azimuth by the mechanisms that were available at that time, and indeed for many centuries thereafter.

109. The cannon of the fourteenth century represent a tremendous advance in the art for so short a time and at a time when the methods of working metals were so crude and so little was known of the metallurgy of iron and the alloys of copper. At the beginning of the century the science of artillery was hardly known. Guns or cannons were simply pots or crude tubes. At the end of the century nearly every nation in Europe was using iron cannon of a caliber so great as to be considered quite out of the question for either manufacture or use to-day. It is interesting to contrast this development with that of the sixteenth century when small high-power guns shooting metal projectiles came into use and within

PLATE 41.



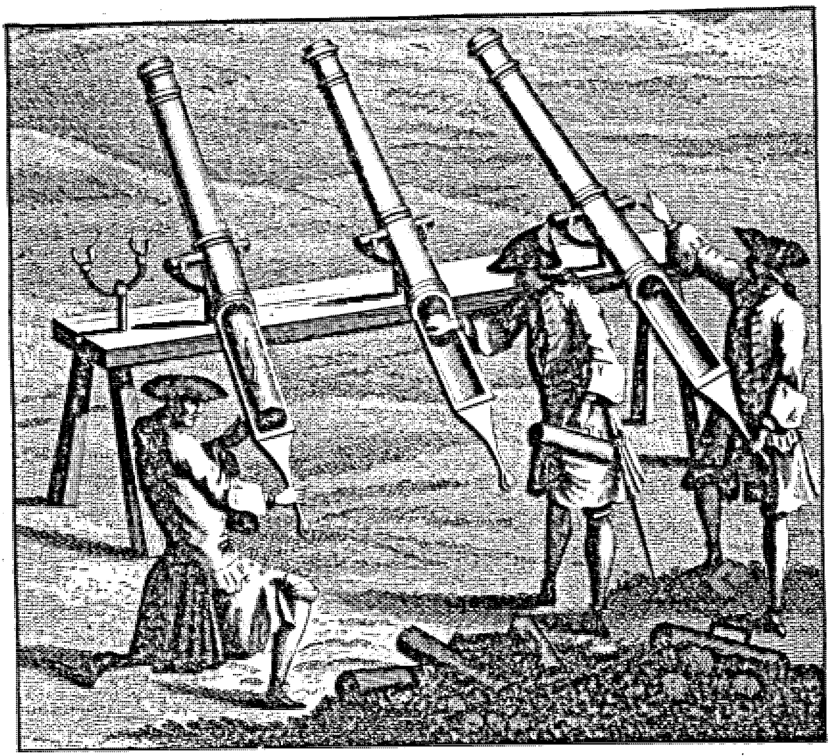
"MONS MEG."

a century practically supplanted the great stone-throwing guns. The early fourteenth century guns were very feeble and it is probably true that their noise produced greater results than the projectiles. The great guns of the end of the century were in a way equally feeble, for the powder was still the ununiform, slow-burning serpentine powder. But they apparently felt a need for guns that would assist in breeching heavy walls or in defending ports against besieging fleets, and finding themselves able to weld wrough-iron bars into a tube of 25 inches diameter they developed such guns as the Dulle Griet, Mons Meg, etc. There is no evidence of the casting of guns of very great weight either from iron or bronze during this century. In fact on this very point lies the great difference between the development of the fourteenth and fifteenth centuries as will be explained later. Plates 39 and 41 serve to represent the scope of the fourteenth century development.

110. This discussion on the cannon of the fourteenth century would not be complete without mention of the breech-loading cannon developed relatively late in the century. Plate 42 represents a cannon used particularly in the defense of fortifications. This

cannon might be termed the earliest distinct type of seacoast or fort gun. It was termed a "wall" gun and seems to have been supported in a metal fork fastened into the wall. It apparently had a wrought-iron trunnion band shrunk or driven on. This, by the way, is also the first known appearance of the scheme of supporting a gun by means of trunnions. The particular merit of this gun was in the provision of a number of breech blocks or cups which might be loaded while others were being inserted or the gun fired.

PLATE 42.



BREECH-LOADING WALL CANNON.

Since this part of our discussion is primarily on gun tubes, it is sufficient to mention merely the existence of a tube open at both ends, in this century of muzzle-loading guns. Another type of breech-loading gun used perhaps before this is shown in Plate 43. This open tube was fastened to a heavy timber or cradle, at the rear end of which a stop of some variety was provided. The breech blocks or cups were then simply wedged between this stop and the gun tube. It is probable that the accidents that resulted from this type of construction resulted in the development of the type de-

scribed above. Neither design proved satisfactory because the crude workmanship made it impossible to secure any satisfactory degree of obturation and the gasses must have annoyed the gunners exceedingly. Open-tube guns appeared periodically from that time on, but were not adopted permanently until about 1850.

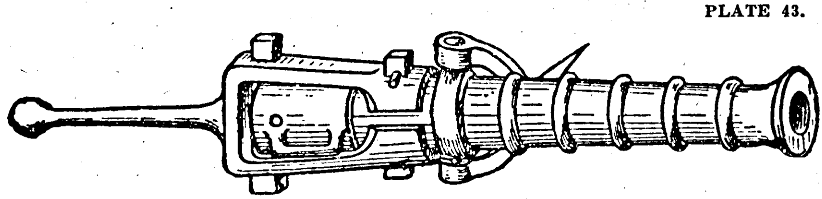
111. Following are comments on references to the construction and use of cannon in the fourteenth century. These comments serve to give one a proper appreciation of the status of the art of making cannon as well as of the science of artillery.

A. The Chronicles of Metz mention in 1324 that powder, projectiles, and cannon are being used in the service of the city and does not seem to consider them in any way extraordinary.

B. An act of the Government of the Republic of Florence of the of the date of 1326 authorizes the casting of balls and cannon for use in the defense of camps and land of the Republic.

C. In 1338 there existed in the Arsenal of the Royal Marine at Rouen, France, a cannon "qui lancait de grosses fleches appelees

PLATE 43.



PORTABLE BREECH LOADER FOR WOOD PARAPETS.

carreauz avec le poudre a canon." The powder was made of 1 pound of saltpeter and one-half pound of "soufre de mélangés."

D. In 1375 a cannon was made at Caen, France, of 2,110 pounds of iron and 200 pounds of steel. The steel was probably a tube made by welding together a number of rods and was cast into the gun as the powder chamber.

E. A manuscript that was in the Asiatic museum in Petrograd at the beginning of the World War and probably compiled by Shems ed Din Mohammed in about 1320 shows tubes for firing both arrows and balls by means of powder.

F. A manuscript preserved in Christ Church Library, Oxford, shows a crude gun shaped like a bottle and used to discharge a dart.

G. Two frescoes in the church of the former monastery of St. Leonardo, in Lecetto, near Siena, which were painted by Paolo sel Maestro Neri in 1340, show a large cylindrical cannon discharging a spherical projectile, and some hand guns.

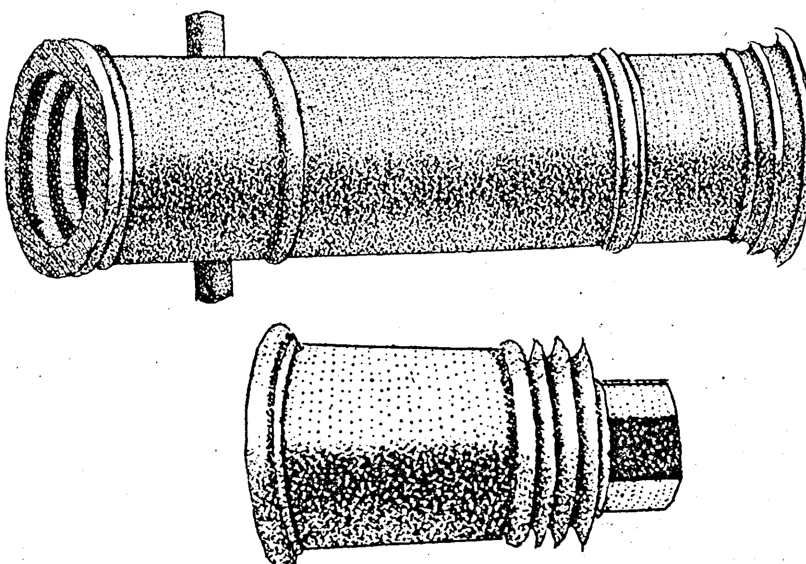
H. In 1331 cannon were used by the Moors in the siege of Alicante. In 1342 cannon were used again by the Moors in the defense of Algeciras against Alphonso XI of Castile.

I. Guns were used by the English in the battle of Crecy in 1346.

J. Two bombardes on wheeled carriages were used by the Venetians in the siege of Inero in 1376.

112. *Fifteenth century cannon.*—The fifteenth century opens with the British, Belgians, and French in the possession of small open-tube or breech-loading "wall" cannon, of wrought iron and bronze, small muzzle-loading bronze mortars cast integral with the base, and at the elevations of 45°, bronze and wrought-iron field guns of relatively small caliber, and the great wrought-iron "bombardes" such as the Dulle Griet, of 25-inch caliber, some of which at least were mounted on wheeled carriages. Practically all nations had gotten as far as they could in the development of wrought-iron guns and

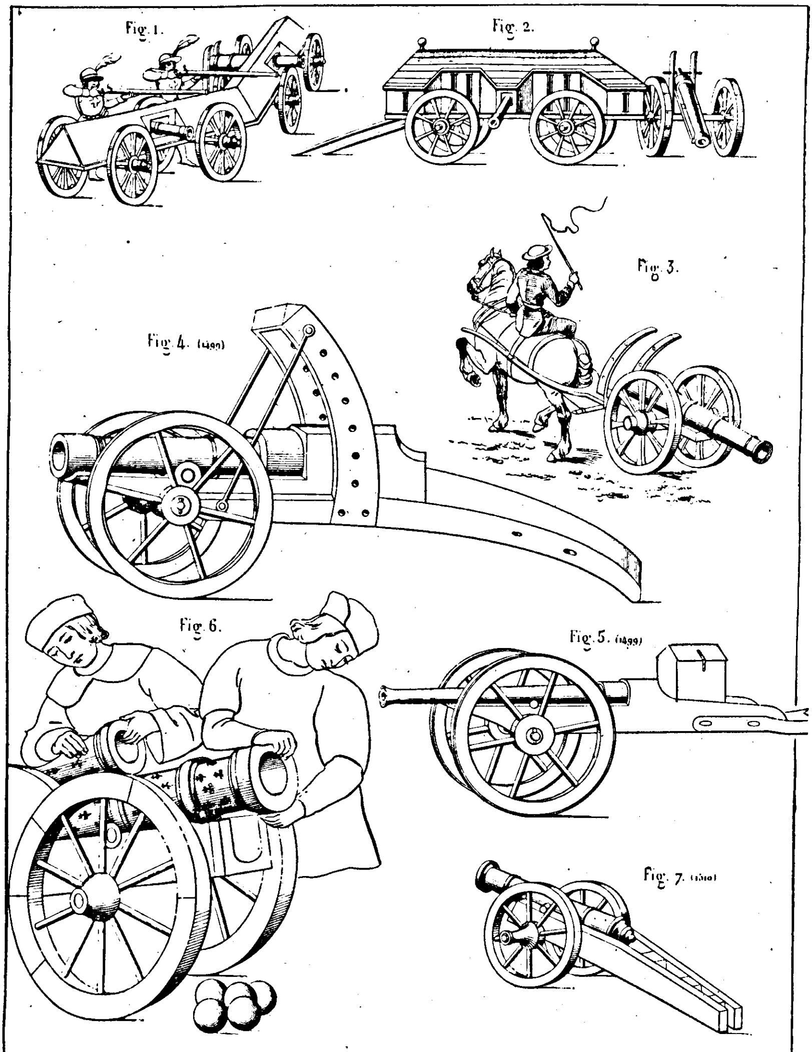
PLATE 44.



LARGE CALIBER CANNON OF EARLY BREECH-LOADING TYPE.

little further was done. There are no records at hand that indicate further development in the use of this metal until about 1850, when the practice of coiling long rods of wrought iron about a mandril and then welding the coil into a cylinder was adopted. Considerable progress was made, however, in the art of casting in bronze, and in 1468 a great "bombard" was cast, apparently by the Turks, of bronze in Constantinople. This "bombard" is in two pieces, Plate 44. It has a bore of 25 inches diameter and a powder chamber with inside diameter of 10 inches. The two pieces are screwed together. One of the projectiles used was a granite shot weighing 672 pounds. The gun complete weighs 18¾ tons. These guns were made to serve as "coast defense" guns and were so placed as to prevent the passage of

PLATE 45.



Lemaitre sc.

CAST CANNON OF THE FIFTEENTH CENTURY.

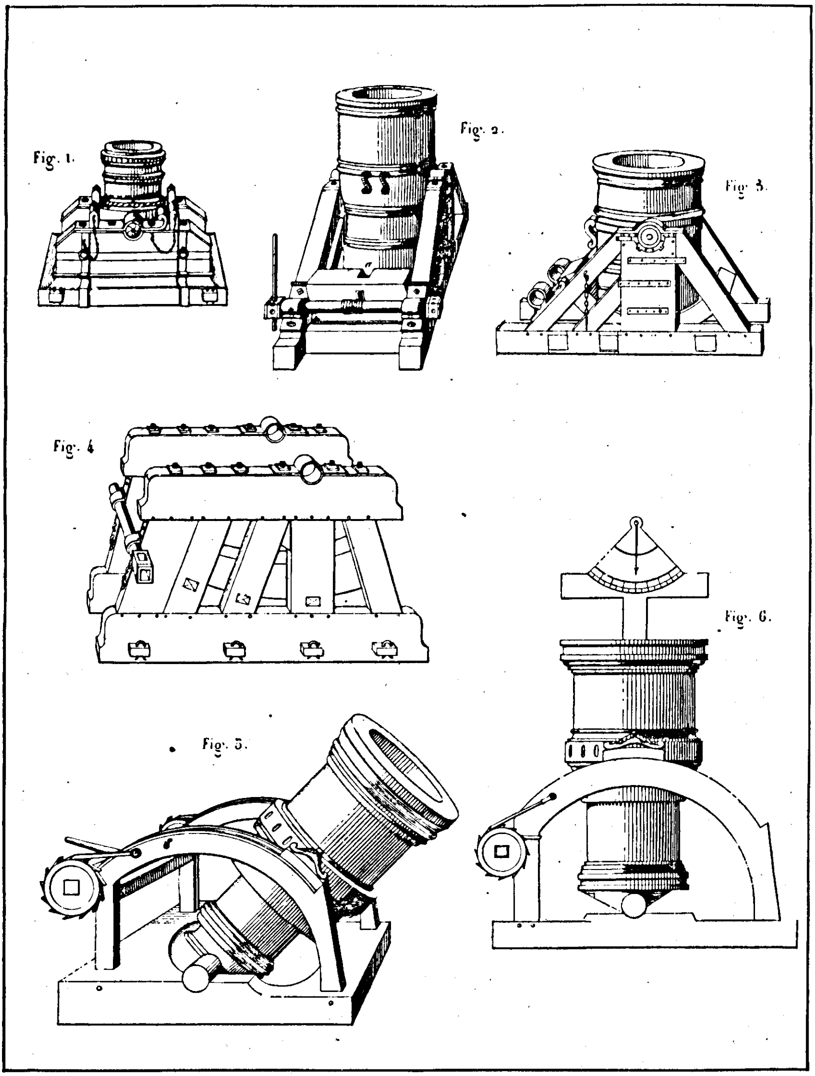
the Dardanelles. They were in use even as late as 1807, when a British squadron under Sir John Duckworth forced the straits. In this engagement 6 men-of-war (wood) were more or less damaged and 126 men killed or wounded by these massive stone projectiles. Other cannon typical of this period are shown in Plate 45.

113. *Sixteenth century cannon.*—At the beginning of the century we find the great cast-bronze and forged wrought-iron bombardes still popular. The art of casting in bronze had been developed during the previous century to the point of casting the great tubes weighing as much as 18 tons. Early in this century the greatest gun that probably was ever made was cast in Moscow. This was the great so-called Mortar of Moscow, having a bore of 36 inches and a powder chamber tapering from 19 to 18 inches. Its total length was 18 feet. The wrought-iron gun Dulle Griet was 197 inches, as compared with the 216 inches of this cast gun. This gun or mortar was, of course, used to throw stone projectiles. A sphere of granite 36 inches in diameter would weigh about 2,200 pounds. No records are available to indicate the weight of this gun nor the methods of handling it. It is assumed that it was simply trussed up as the other bombardes and kept at one elevation at least during any one engagement.

114. Early in this century one finds the use of metal projectiles becoming more common as a consequence of the more general production and use of casting iron. The introduction and more general use of metal projectiles had the effect of putting into disuse the great bombardes by the middle of the century and the substitution of long cast-bronze and forged wrought-iron cannon of much smaller caliber. In 1544 a bronze cannon of 4.75-inch caliber and of the even at present unusual length of 58 calibers was cast at Utrecht and presented by Charles V to Henry VIII. This cannon is now in Dover Castle and has acquired the facetious name of "Queen Elizabeth's Pocket Pistol." (The small hand gun termed a "pistol" is said to have gotten its name from the fact that such arms were first made in Pistoia, Italy.) The longer high-powered cast and forged cannon using the metal projectiles were really as powerful as the rather feeble large-caliber bombardes. The mobility of the smaller cannon caused them to supplant the great unwieldy type.

115. In this development of the art of casting both in bronze and iron we see also the appearance of trunnions more generally, and in fact guns of this century came generally to be supported on their crude carriages by means of trunnions. The mortars were cast with trunnions practically flush with the breach end, Plate 46, and were mounted on heavy timber platforms with grooves in which the trunnions rested and wedges in front for changing the elevation. Iron founders were introduced into England for the

PLATE 46.



SIXTEENTH CENTURY MORTARS AND MOUNTS.

purpose of casting cannon in about 1540. The art of casting in iron was more highly developed on the Continent than in England. As the art of casting and forging became more highly developed during this century and guns were made in relatively larger numbers, there was some attempt at the establishment of standard calibers. This did not get very far, but the sixteenth century must be given the credit for starting it. Some little work was done also in developing schemes for preventing the escape of gases past the projectiles. Round and cylindrical projectiles were coated with lead and rammed laboriously down the bores of the guns.

116. Probably the most notable discovery for which the century should be remembered is that of rifling. Rifles, presumably hand, are said to have been invented by August Kotter, of Nuremberg, in 1520. Since the evidence is good, one may accept this statement as a fact, or as at least indicating the earliest knowledge of the principle of rifling early in this century. The unexplained question is how it was discovered. One theory is that the first rifled handguns had straight grooves which were introduced in an attempt to secure better obturation with a lead bullet than had been secured with a smoothbore gun. A modification of the straight grooves to curved, still with the desire of securing better obturation, brought about results in the stabilizing of a cylindrical bullet that had not been expected. This really seems a tenable theory. The only other on which one could work would be a recognition of the principle of the gyroscope and its application to gun projectiles. Since the principle of the gyroscope does not seem to have been recognized until nearly 1750, it does not seem reasonable to connect a recognition of this principle with the spiral grooving of the first guns. Further, cannon were being developed by men of the trade guilds and not by the mathematicians or so-called scientists, and though highly skilled these tradesmen rarely had any education of letters or appreciation of the application of the various principles of mechanics. It appears, therefore, that the discovery of the merits of rifling must have been through accident, and one should not consider this so surprising, for many more wonderful principles have been discovered through stranger accidents.

117. The principle of rifling was not generally adopted during the sixteenth century nor in fact for several centuries afterwards. Rifles were introduced into several continental armies during the seventeenth century, but in each case were withdrawn, principally because of the excessive time required to load them. In those few cannon that were rifled during this century two, three, or four grooves were provided and the projectiles, solid, were fitted with soft metal lugs to fit into the grooves. The guns were relatively

weak and did not stand the pressures developed, and rifling did not meet with tremendous favor.

118. The sixteenth century developments may be summarized as covering the casting of the largest caliber bombard ever made and the gradual abandonment of the bombard as a type too unwieldy to retain, the development of extremely long cast-bronze and forged wrought-iron small-caliber cannon, the introduction of metal projectiles, and the discovery of the principle of rifling. The use of trunnions to support guns on their carriages became more common, and some little progress was made in the standardizing of the calibers of cannon. Metal projectiles were also coated with lead to secure better obturation.

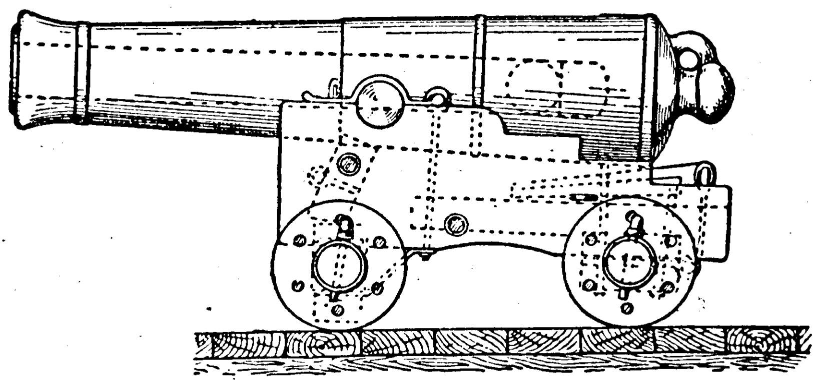
119. *Seventeenth century cannon.*—During this century relatively little was done in the development of cannon. Some progress was made in the art of casting, some little improvement was made in the accuracy with which cannon were cast, cannon became somewhat more ornate, and quite a little was done in the standardizing of sizes of cannon both as to bore and length. During this century cannon were classified in England as cannon royal or double cannon, weighing about 8,000 pounds and shooting solid shot of 60, 62, and 63 pounds; whole cannon, weight 7,000 pounds, shooting solid shot of 38, 39, and 40 pounds; and demi cannon, weight 6,000 pounds, and firing shot of 28 or 30 pounds. These cannon were also styled cannon of 6, 7, and 8. Incidentally the earliest use of the word "cannon" (L. canna, tube) to indicate a piece of artillery seems to have been in 1474. Cannon of a weight less than 6,000 pounds were called culverin, saker, falcon, 24 pounds, 4-pounders, etc., respectively. There is a record that Cromwell took with him to Ireland two cannon of 8, two cannon of 7, two demi cannon, and two 24-pounders.

120. The indications are that by the beginning of the seventeenth century cannon tubes had gotten considerably ahead of carriages, ammunition, projectiles, and the science of artillery in general. This may account for the lack of development in design of cannon tubes during both this and most of the next century. It will be remembered that the first shell were used late in the sixteenth century and were developed to a higher degree during the seventeenth. Fuses received more attention, and multiple shot, "chain" and "case," were first employed. Coast or fort guns were mounted on wood carriages such as is illustrated in Plate 47. These guns were generally supplied with trunnions and were capable of being elevated a few degrees by means of the wedge under the breech end. Iron breech-loading guns were also in use, but chiefly on ships in restricted places where it would be nearly impossible to load them from the

muzzle. Such guns were without trunnions and were mounted on the original type of wood cradle, which was in this case grooved on the underside to permit it to slide on the traversing or directing bar pivoted at its front end. Both the bronze and iron cannon were cast heavier during this century, Plate 48, because of the greater strength of the grained or corned powder that came into use. The larger cannon were of course made of cast iron, while the smaller field guns were made of bronze.

121. *Eighteenth century cannon.*—This century, as the last, is marked largely by refinement in design, increase in weight of guns, improvement in the quality of materials used, and improvement in the methods employed in casting and machining cannon tubes. The breech-loading gun was still more of a curiosity than otherwise; cast iron and steel were both looked upon with disfavor, more be-

PLATE 47.

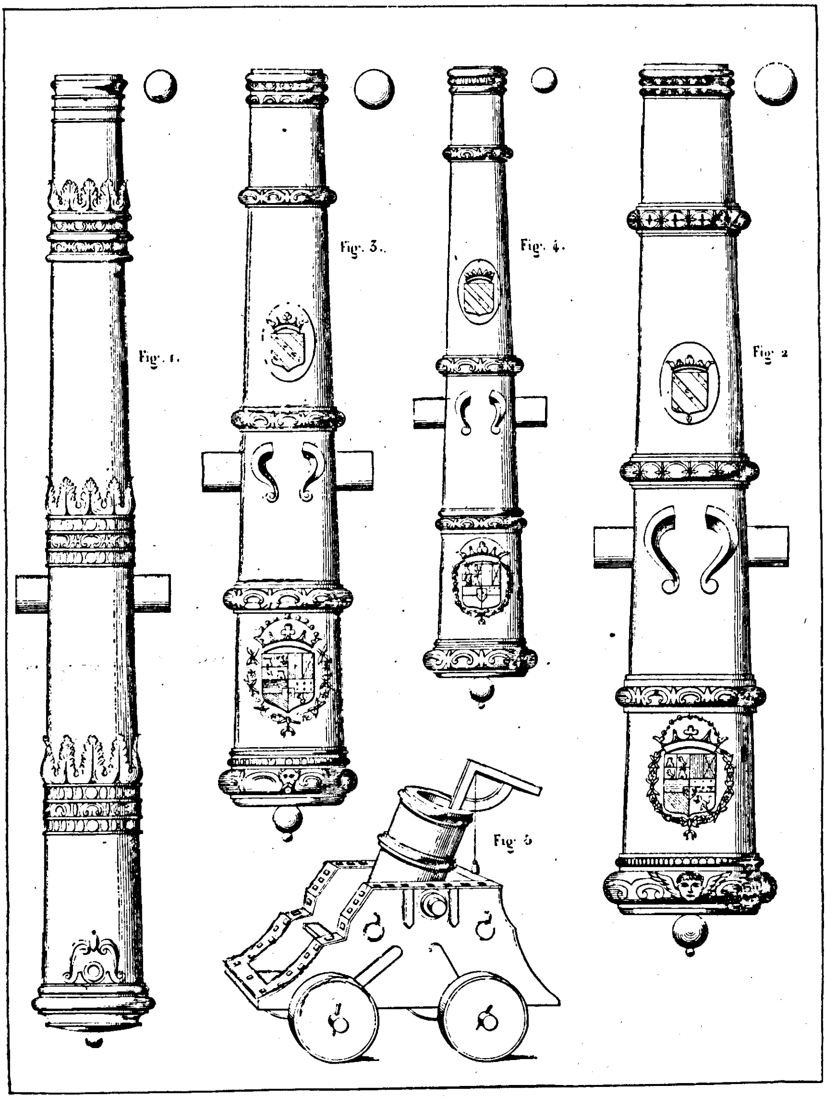


OLD TYPE SHIP AND COAST GUN AND CARRIAGE.

cause of ignorance of the proper principles of the design of guns than from any fault of the metal. Bronze was considered the best material available. Little further improvement had been made in powder. It is true, however, that rifled muzzle-loading cannon were coming gradually more into favor, and considerable improvement was made in the design of carriages. This will be discussed later under that heading.

122. Some quotations from the book written by Louis de Toussard at the end of this century on the methods employed in the casting of cannon will be of interest. It has been mentioned that de Toussard was an officer in the army of General Washington and wrote this book at the request of the general. He describes in great detail the methods and formulas for the making of powder and the furnaces and machinery used in manufacturing cannon. Following

PLATE 48.



CANNON AND MORTAR OF THE SEVENTEENTH CENTURY.

are some extracts from this book with copies of some of his illustrations:

Section III.—Toussard's Artillerist.

ON THE CASTING OF CANNON AND MORTARS.

Cannon were formerly cast with a core, for which purpose a shaft of iron, covered with clay and supported at the breech by an iron frame with three legs, was placed in the center of the mould. But, notwithstanding all the precautions taken to place this core with precision, the bore was never perfectly straight, nor was the thickness uniform, because the core could not sustain the fall and heat of so great a quantity of metal without bending and warping considerably. Chambers or cavities were also occasioned by the air contained in the clay round the shaft, which the heat expands, and which lodges in the piece, finding no issue when the metal has passed it. To obviate these defects, guns are now cast solid, by which method the bores are always straight, and the chambers very rare.[1]

Yet even this method of casting is said to be attended with defects. The tin, which cools last (because the heat of the copper keeps it a long time in fusion), escapes in great quantity as the copper assumes a certain consistency, and the parts nearest the mould always cool first. The tin then runs towards the center in a greater proportion than is necessary to make brass of the best quality; so that, after having taken out with the cutters a cylinder of metal sufficient to form the bore of the piece, the remainder of the mass of metal has no longer a well-proportioned mixture.

The custom of turning the pieces, that the bore may be concentric with the exterior surface, has also its inconveniences; it takes away a great part or the whole of the exterior crust, which is extremely hard, because the parts of the metal nearest the mould, cooling first, have retained the tin, which is there divided in the due proportion. These reasons have induced those who do not wish to attribute the destruction of the guns to the concussions of the balls in the bore to think that they are ruined because only the softest part remains. But, even were this satisfactorily proved, still the straightness of the bore, and their greater accuracy in firing, fully counterbalances the diminution in the duration of the cannon.[2]

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[1] In the method of casting with a core, as well as in that of casting solid, the air in- closed in the mould and expanded by the heat occasions chambers. It is thought that this would be avoided if the melted metal, instead of falling from the top of the mould, were to enter below; the air would then easily escape as fast as the metal would rise in the mould.

[2] It is a fact well known, that in almost all substances which are cast in moulds, passing from a state of fluidity to that of solidity, their mass varies in hardness, becoming more porous as it approaches the axis of the mass; and this increases in pro- portion to the bulk. Cannon cast solid ought then, according to this rule, to have more density and force at their exterior surface than on the sides of the bores which are nearer the axis of the mass; and this diminution of density and force should be greater in proportion in the larger than in the smaller calibers, on account of the increase of bulk. It follows, therefore, that with an equal pressure of the elastic fluid, the sinking of the metal under the projectile, or by its concussions, must be greater in the larger than in the smaller calibers. To conclude, it should be added to this, 1st, that with an equal density of the mixture, the lodgment of the ball, the pernicious effect of this inevitable force of pressure, must be more speedy in proportion to the size of the piece; 2d, that with an equal velocity, the concussions are proportioned to the weights of the projectiles; they must, therefore, be more violent and destructive in the 24 than in the 16 pounders, and more in these last than in the 12 pounders, etc.; 3d, the concussions are not only more violent in the large guns, as has just been shown, but they also begin sooner and are more frequent. (Martilliere.)

Cores do not cause the same inconveniences in mortars; therefore it appears that it would be advantageous to cast them all in this manner, and to take off as little as possible of the sides of the bore in smoothing them. It is certain that mortars, by this method, would have a greater power of resistance, and consequently a longer duration. However, 10-inch mortars for short ranges, those of 8 inches, and howitzers, are cast solid and afterwards bored. There are, therefore, only the 12-inch mortars, those of 10 inches for great ranges, and stone mortars, that are cast with a core. For this operation the mould is suspended above the core, which is introduced into it in such a manner that no part of it remains after the casting, as was sometimes practised in the casting of cannon when the base of the core remained sunk in the metal. This method, the reverse of that formerly employed in the fabrication of cannon with the core, requires much care and art to execute it with accuracy. The excess of metal is taken off with the last cutter after its axis has been determined, and the piece is turned in the same manner as other firearms.

In the field 12, 8, and 4 pounders the axis of the trunnions passes through the center of the bore. Some affirm that if the upper line of those trunnions passed through the center of the bore, as in the 24 and 16 pounders, they would be more solid; because in casting, the metal, having reached the height of the trunnions, is obliged to divide or separate to supply the dolphins and trunnions, and the mixture being altered in cooling, this part of the reinforcement not having sufficient thickness, and not being capable of being supplied like the rest from the metal above, is therefore less dense than the breech and chace. Besides, if the trunnions were placed as they propose, the cannon would be more elevated above the cheeks of the carriage, which could not but be advantageous for their service in the field.

It has long been an object of attention to discover some method of ameliorating the castings, and of giving to the brass such a power of resistance as to make it capable of longer service. There have been firearms cast according to the processes of able founders, who had exercised their art 20 years in Austria, which had very great power of resistance; among others some field 4 pounders which were fired 5,000 times without being injured.

These proofs were renewed in 1786, and the 4 and 8 pounders of the same founders were superior to those of the ancient casting, having, with the others, been fired 3,000 times, with less injury. The 12 pounders had not the same advantage over those of the ancient casting; 916 discharges entirely ruined the former, while the latter were yet serviceable after having been fired 2,400 times.

All these fieldpieces were proved with the same kind of fixed shot used in war. This method preserves the guns very much. The ball with the shoe forms a cylinder which slides along the bore, and, which not being liable to any rotatory motion, does not produce those violent concussions which very soon destroy the gun. The shoe does not separate from the ball till it has left the piece; an evidence of this is that in these proofs the greatest part of the shoes were found, either whole or broken, at 50, 60, and 100 yards from the butt, whereas by themselves they could not have gone 30 yards from the piece, owing to the resistance of the air. In this case reason agrees with experience, since a 4 pounder (one of those which were

fired 3,000 times with fixed shot) was destroyed in 576 discharges (without the shoe).

The proof of this is more evident in the 24 and 16 pounders, some of which were destroyed in 37 shots, others in 50, one in 150, another in 720, one in 825, another of the same casting as the last, and as that which was destroyed in 37 discharges, was fired 3,400 times. It would be wrong, therefore, to attribute their rapid destruction merely to the quality of the metal. There are many cannon of large calibers, and of ancient casting, which have been used a long time, and which may be serviceable much longer.

Let us examine the proceedings previous to the fusion of the metal in the furnace.

OF THE PROCEEDINGS IN THE FABRICATION.

The principal operations in the casting of artillery consist, 1st, in the modelling; 2d, in the fusing and casting of the metal; 3d, in the boring; 4th, in the piercing of the vent and repair of imperfections in the casting; and 5thly, in the proof and visits which insure the quality of the same guns.

We will treat these parts separately, but as succinctly as the limits of this publication will allow. Without speaking of the moulds in earth, which are sufficiently known in this country, we will begin with the moulds in sand.

MOULDS IN SAND.

When the moulds are made in sand, the model of the piece, with the spruce, is of copper or iron.[3] The first of these metals is preferable, because its surface is smoother, and it is more easily drawn from the sand. The model is divided into pieces, which are moulded separately, and the division is such that each piece may easily be drawn out. Each piece has a flask of cast iron, nearly of the same height as itself, and composed of two parts which are joined lengthwise and fastened together with pins and keys. The model is placed in the center of the flask, and the interval filled with sand, tempered with clay, which is well rammed to give it a sufficient hardness.

The brass model is hollow, as well to diminish its weight as for the convenience of working. If the piece is to have some projecting parts, as the trunnions or astragal, etc., the models of these objects are applied to that of the cannon, and fastened there with screws which are turned in the interior of the model. When the piece is moulded the screws are unfixed and the models withdrawn. The different parts of the mould are then dried in a stove, after which a coat of coal dust, diluted with water, is spread over the interior. In this state the parts of the mould are let down successively into the pit, where they are placed upon each other and fastened together with pins and keys; the mould is then ready to receive the metal.

This slight description is far from being sufficient for those who wish to put into execution the moulding in sand. We will, therefore, enter into the details respecting each part that we may deem necessary.

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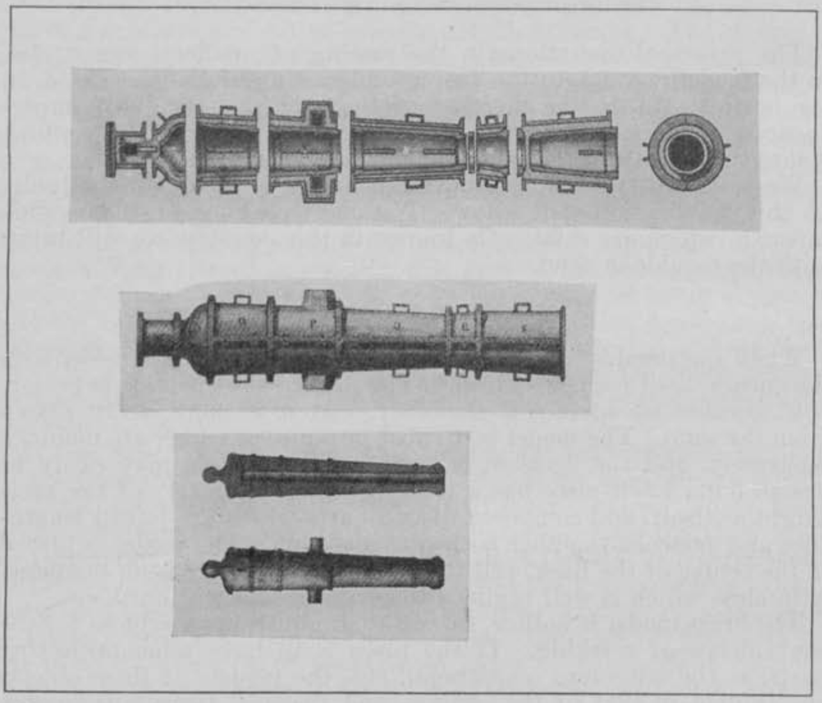
[3] In the French national foundries the models are of pewter.

CONSTRUCTION OF THE FLASKS.

The cast-iron flask of a cannon mould is composed of as many parts, or particular flasks, as there are pieces in the model. Each of these flasks is divided into two parts lengthwise of the cannon, that the cannon may be easily cleared of the sand which envelops it when it is cast; and round each of the parts there are projecting edges, by means of which the whole may be put together and fastened with pins and keys. The longitudinal and straight edges serve to unite the two halves of one flask, and the circular edges connect two adjacent flasks. It is evident that these edges must be pierced with holes in which the

PLATE 49.



CAST CANNON AND MOLD.

corresponding pins must enter, and that the edges, which are to be in contact, must exactly correspond, Plate 49.

To cast the parts of the flasks, a demicylinder, of the same diameter and exterior form of the part to be cast, and some inches longer than this part, is made in plaster or wood. The ends should be rounded that it may easily be drawn from the sand. At each of these ends is made a groove from six to nine lines in breadth, and as much in depth, according to the caliber of the piece for which the flask is designed; for instance, for a 36 pounder nine lines are given to these grooves, and somewhat less for smaller calibers. In these grooves are placed circular pieces of wood, 3 or 4 inches broad, which form the connecting edges of two adjacent flasks. The whole being placed

upon a wooden platform, a straight piece of board (of the same dimensions as the circular pieces) is put on each side, and forms the connecting edge of the parts of the same flask. A frame of wood, or of cast iron, is then put on, and the sand rammed into the intervals in the ordinary manner. The casting funnel is placed on the flask, and the air holes made on the most elevated parts of the edges.

When this part of the mould is made, it is raised up and turned. The demicylinder of plaster or wood remains upon the platform, and the straight as well as the circular pieces of wood remain in the sand. The circular pieces form a projection equal to the part that was in the groove of the demicylinder. The space between these projections is filled with small straight pieces of wood of the same thickness as the projection. The second part of the frame is put on, the sand is rammed as usual and the mould turned over. It is then opened, all the little pieces of board (which readily quit the sand) are drawn out, and the mould is finished.

These parts of the flask are cast without drying the moulds. Care should be taken not to ram the sand too much.

To avoid the trouble of piercing holes for the handles and for the pins, which serve to unite the parts of the flask after the iron is cold, small parcels of earth are used, which will produce holes in the casting; but then great attention should be paid that these parcels of earth may be so placed that the holes shall exactly correspond.

The flask, which corresponds to that part of the model in which the trunnions are to be formed, must have two arms, one on each half of the flask, in which the trunnions should be moulded. To mould these arms, it is necessary to adjust to the demicylinder an octagonal box, and to make it pretty large in order that the two parts of the mould (that of the interior and that of the exterior) may be easily drawn out.

The flask of the breech cannot be cast in this manner; it should have nearly the same profile as this part of the cannon; it is turned with patterns made with two boards in which the profile is cut, one for the interior and the other for the exterior.

The handles of each part of the flask, and the connecting pins and keys, are riveted while hot.[4]

OF THE MODELS.

The surfaces of the several pieces of the model should be very smooth and straight. If there are any cavities in the middle, the model cannot be drawn from the mould.

Each piece should be a little longer than the corresponding part of the cannon, on account of the contraction of the metal in cooling. This contraction, which is not exactly the same in all cast iron, is estimated at three-quarters of a line to a foot of the length. Its effect on the diameter is too inconsiderable to deserve much attention.

The points of division of the model or pieces are, 1st, at the breech; 2d, at the first reinforce; 3d, at the second reinforce; 4th, at the chace; 5th, at the tulip or swelling of the muzzle; and all these pieces, placed in their proper order upon each other,

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[4] The explanations which are annexed to the eight additional plates render it unnecessary to multiply references in this chapter.

should represent the complete model with its sprucehead. To prevent the different pieces from experiencing any derangement in the operation of moulding, they are joined to each other by a gorge and groove nearly in the manner of the two parts of a snuffbox. This gorge and groove should be some lines in depth, and that part of the piece which is to be introduced into the contiguous piece, should be in addition to the length of the first, so that the two pieces, when united, may both be of the determined length.

We have already mentioned how the models of the projecting parts are adjusted; a few additional observations, however, must be made on the astragal. If the model of the astragal was a circle in one piece, with the necessary moulding, after having drawn from the mould the model of the part of the cannon to which the astragal belongs, this circle would remain in the sand, and it would be impossible to take it out. This circle then must be divided into several parts, which are taken out separately. It is generally divided into three parts; but this division should not be made in cuts directed from the circumference to the center because the different parts would then be joined like the stakes of an arch, and it would be impossible to take them out. They should be cut in an eccentric and slanting direction, that the pieces may then be taken out with ease. It is evident that each part must be screwed separately on the body of the model.

OF THE SAND.

Nature seldom produces a sand perfectly proper for moulding; but when the qualities which sand ought to have are known it is never difficult to compose one which may have every requisite.

1. The sand must not be of such a nature as to be melted by the great heat which it experiences from the melted metal; for it then vitrifies at the surface, forms protuberances, of which it is difficult to clear the metal.

2. There should not be too much clay in it, because it would contract too much in drying.

3. It should be rough and angular; for if its particles were round they could not unite, and they would not hold together in the moulding.

4. The sand should not be pure, because there would be no adherence in it, and it would not preserve the form given to it.

Therefore, to compose a sand which may possess all the necessary qualities, we must choose that which is quartzy, angular, rather coarse, and very refractory; that is, which will not vitrify even with the greatest heat; then moisten it with water in which some clay has been diluted, and mix it well. There is clay enough in the composition, when, if we take a handful while it is yet moist, squeeze it, and then open the hand, the mass retains the form given to it by the compression.

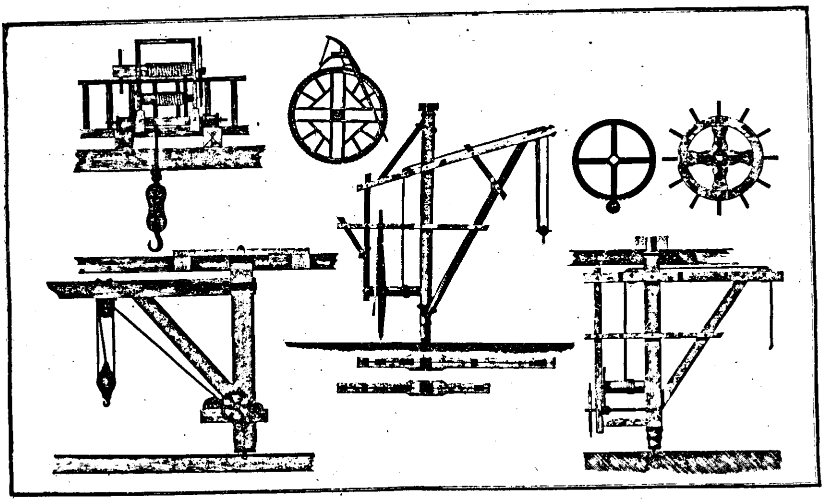
When the baking which it is necessary to give the moulds, and the heat of the metal, have hardened the clay and deprived it of its adhesive quality, it is moistened with water in which a little clay is diluted. By this means the same sand will last a long time. But if sand is not to be procured, sifted cement may be used in following the preceding process, provided the burnt earth (of which the cement is made) is sufficiently refractory not to vitrify by the heat of the metal in fusion.

OF THE MOULDING.

The moulding of a cannon is begun by taking the model of the breech, which is placed on a wooden platform; the model, with the part of the flask that is to envelop it, is then covered, and the sand rammed between them. When that is done, the whole is turned over, and the surface of the sand compressed between the model and the flask is sprinkled with pulverized charcoal, in order that the sand of the succeeding piece may not adhere to it when it is necessary to separate them to draw the parts of the model from the interior of the mould.

Then, by means of a crane, Plate 50, which is placed in a convenient situation for this purpose, the model of the first reinforce is put gently on that of the breech, so that the gorge of the one may enter exactly into the groove of the other. The flask of the

PLATE 50.



TYPES OF CRANES USED IN GUN FACTORY.

first reinforce is afterwards raised with the crane, so as to pass over its model and let down gently until it rests upon the flask of the breech, taking care to turn it so that the holes in its lower edge may correspond with those in the edge of the flask of the breech.

That being done, the sand is rammed in between the model and the flask with wooden rammers. The sand must be put in gradually; if too much is thrown in at once, only the upper part will be rammed; the lower part will not be sufficiently hardened, and will not be able to resist the pressure of the metal in fusion, which will cause considerable inequalities in the surface of the gun. The rammers should be so small as not to strike upon too great a surface, in order that the moulding may be more complete. When one piece is entirely moulded, the model and flask of the contiguous piece is put upon it, for which the same means are used, and thus in succession until the sprucehead is moulded.

The trunnions are moulded at the side, and this part of the flask is then closed by a plate at each end which is fastened with pins to the other parts of the mould.

The iron guns cast for the Navy have no other projecting parts but the trunnions and astragals; those of brass for the land service have dolphins. The most convenient manner of moulding them is to screw the models of the dolphins, full and without any void, on the models of the piece; for this purpose the flask must have a swelling in this part which affords the necessary space. Small pieces are then moulded separately, which have exactly the form of the void of the dolphins; and when the models of the piece and of the full dolphins are drawn from the mould, these small pieces are introduced into the place which they are to occupy. They should enter, like a drawer, into spaces made for that purpose by the models of the full dolphins. By this simple process we may dispense with a series of operations which require much attention and address.

When a flask is put upon another which has just been filled with sand, care must be taken to place between the two flasks three small wooden wedges half a line in thickness, to prevent the two parts of the flask from touching; because the sand withdraws a little in drying, and when the mould is afterwards placed for casting, there might be, without this precaution, an interval between the sand of the two parts of the flask, through which the metal might run out. Besides the piece would run the risk of not being perfectly straight. These wedges also serve to dress the flasks in such a manner that the model may always be in the center.

The moulding being finished, the mould is taken to pieces in order to draw out the different parts of the model. For this purpose all flasks are successively raised with the crane, which carry with them the sand and models which they contain; they are let down upon the ground and turned so that the large end may be uppermost. The screws which fasten the projecting parts to the model are then taken from the interior, if there are any; the model is then struck with a wooden mallet in order to detach it from the sand. It is raised gently with the crane, and care taken that it does not oscillate against the sand, the form of which it would spoil. If this accident happens, it must be repaired by putting in sand with a small trowel; this additional part must be made to adhere to the first by means of long pins of iron wire.

The flasks, after the models have been taken out, are carried to the stove to be dried.

OF THE STOVE.

The stove is a room 10 or 12 feet square, lined on the inside with brick work, if possible, and arched. There is a hole in the arch to let the smoke out. In the middle of this chamber is an iron grate, in the form of a millhopper, 5 feet square at the top, diminished towards the bottom, and composed of iron bars an inch square in which wood or stonecoal is burned.

The moulds are ranged round this grate. There may be several rows on the top of each other; but they must be supported by iron bars, the ends of which are fastened in the walls.

It requires about 15 hours to dry the moulds with a pretty strong heat. They must not, however, be made red hot, because that would strain the flasks and soon destroy them.

When the moulds are taken out of the stove, and before they are put together, it is necessary to give them the coat of pulverized charcoal, diluted with clayed water, for which purpose a long-haired brush is used. As this mixture dries as fast as it is put on, care should be taken not to pass the brush several times over the same spot, because it would occasion unequal thicknesses.

OF THE CRANE.

(Plate 50.)

The pieces of the model of a cannon, and the parts of the flask corresponding to them, are very heavy. They must be placed upon each other with care, and without violence. In a cannon furnace it is therefore indispensable to establish a crane to facilitate the work as well as to save the number of hands which would otherwise be wanted at some moments, and which at other times would have nothing to do.

This crane should have an arm at least 10 feet long and should be about 15 or 16 feet high. There should be at the end of the arm a pulley, the rope of which should wind round an horizontal windlass, fixed to the vertical shaft of the crane. It is also necessary to adjust a cogwheel to the axis of this windlass and a small pinion to the handle by which it is turned.

The crane should serve not only to move the pieces of the models and the flasks for the operation of moulding, but also to place the parts of the mould in the pit, and to draw out the cannon when cast. The vertical shaft ought to be placed in such a manner that, in turning, the end of the arm may be placed over the pit, and over every part of the space in which they work.

SECTION V.

OF FURNACES, AND FUSING OF IRON METAL.

The mould being placed in the pit, if the piece is small, or if the crucible of the furnace contains metal enough for the casting, a canal is formed to conduct the metal from the hole into the crucible of the furnace to the mouth of the mould, and which is so lengthened that the metal may fall vertically into the mould. The earth of this gutter should not be too dry because the metal would carry it into the mould; neither ought it to be too wet, as this would occasion explosions which might cause the casting to fail; it has the proper moisture when it can be beaten and smoothed at the surface. The gutter is traversed by a thin piece of board, which, sinking a little into the stream of the metal, stops the scoria which float on the surface, and suffer only the pure metal to pass. When the mould is full to the top of the spruce, the stream is stopped by driving the dam into the ground.

The crucibles of blast furnaces do not contain metal enough for large pieces, each of which requires a casting of ten or eleven thousand pounds. This is remedied by building near the blast furnace one or more air furnaces fourneaux a reverbere, which are only intended to reflux the metal coming from other founderies, and to supply the quantity required for the casting. The gutters of these furnaces are united to that of the blast furnace. The

crucibles of the air furnaces are first pierced, because the metal, acquiring more tenacity at the second smelting, is better calculated for the breech of the piece, which should be capable of the greatest resistance. The crucible of the blast furnace is then pierced in order to finish the chace and the spruce; in such manner, however, that there may be no interval between the flowing of the two streams.

Air furnaces are heated with a combustible matter which produces flame. The fire is not animated by bellows; its activity is excited by the draught of air, which is the greater in proportion to the height of the chimney. To reach the chimney, the flame is obliged to strike the metal, which is placed on an inclined hearth, and as it melts, runs and collects in the crucible of the furnace.

The art of smelting iron in an air furnace consists principally in the quickness with which it is put in fusion. This metal easily loses the coal which it has absorbed in the blast furnace, and, if it is kept long in the fire before the degree of heat is sufficient to melt it, it loses its fusibility; it is, therefore, requisite that the furnace should have a form which may receive, in the shortest time, the greatest degree of heat.

The name of reverberatory, given to these furnaces, arose from the opinion that the vault of this furnace reflected the flame upon the metal, and increased the temperature, and hence great importance was attached to the form of the vault. This form should be such as to be firm and last a long time; but it has no effect on the temperature. What chiefly contributes to give a very high degree of heat is the smallness of capacity of the furnace. It is much more difficult to raise a large space than to raise a small one to a given temperature. The principal attention, therefore, in the construction of air furnaces is to suppress all useless capacity and to avoid all cavities which are not absolutely necessary. It must also be observed that the volume of the flame, diminishing in proportion to the distance from the body in combustion, the dimensions of the interior arch of the furnace should also diminish from the grate to the chimney.

The furnace, exclusive of the chimney, is composed of three principal parts—the fireplace, the hearth, and the crucible.

The grate of the fireplace is very broad, and should have a greater surface than the interior arch of the furnace, even at the broadest part; it should be placed 8 inches below the level of the hearth. If the coals be small, the grate must be raised 5 inches; for this purpose, the two lintels, which support the bars of the grate, should be set in a groove made in the brick work, that they may be raised or lowered at pleasure, in order that as little a weight at the other end, by means of which it is easily raised or lowered. The third door is placed at the back part of the furnace about the crucible; through this door the metal is stirred when in fusion to mix it and render its quality uniform throughout. Through this door they also take out the metal in ladles for some small castings. This door is closed by a square of burnt earth, in the middle of which a hole is formed, by means of which the interior of the furnace may be viewed and the state of the fusion ascertained. This hole is also closed with earth. The crevices at the sides of the two last doors are closed with mould sand.

When the smelting is to take place, the furnace is heated till the interior is white hot and till the sand of the hearth begins to vitrify, which is known by striking upon it with an iron bar. This precaution is necessary to prevent the metal from sinking into the sand.

When the furnace is heated to this degree, it is charged with as much as 5,000 weight of metal in pieces. The charge is put in with the utmost expedition, that the interior of the furnace may not be too much cooled during the operation.

To facilitate the operation of charging, it is advantageous to have the pigs cast in the blast furnace of about 100 weight; however, much larger pieces may be put in, as fragments of old cannon and the spruces of those which have been previously cast. The furnace being charged, the crevices of the doors are stopped up, and in two or three hours the metal should be entirely fused and collected in the bath of the crucible.

When the broken pieces which compose the charge are rusty, which is generally the case, the oxygen of this oxyd attached itself to the coat contained in the metal and burns it; the metal purifies at the surface, and having lost part of the coal which rendered it fusible, it assumes only the clammy form, and the outside of the pieces remain in a lump upon the hearth. In this case, a moment before the casting, the door is a little opened and this mass is raised with a bar to facilitate the running of the parts which are in fusion into the bath of the crucible.

The name of carcas is given to the masses which thus resist the fusion. This iron, which has undergone the purification to a certain degree, should be carried to the forge to be wrought into bars.

Several castings may be made successively by taking the precaution to clean the floor of the furnaces, and to remove all the scoria which may remain there. In this case some sand must be spread over the hearth, the door of which is then shut in order to heat it before it is charged.

In what has been said, we have supposed that the air furnaces ought to be heated with stone coal. As the activity of this combustible is very great (because it contains a great quantity of inflammable matter in a small bulk) the fusion is more rapid, and the metal in fusion experiences less alteration; therefore, whenever it can be procured, stone coal should be preferred. But in countries where it can not be had, air furnaces may be heated with wood. For this purpose the grate of the fireplace must be placed lower, so that between it and the wall of the hearth there may be the length of one stick. The sticks are placed upright on the grate that their inflammation may be more rapid and the action of the fire more powerful. The wood is put in from above by means of an air opening made in the furnace over the fireplace, which opening is shut with a lid as soon as the wood is thrown in. Small wood only should be used, so that the combustion may be more rapid.

The casting being finished, the mould remains in the pit about 10 or 12 hours to give it time to cool and that it may be moved without injury. It is then raised from the pit, the flasks are taken off, and the piece is cleared of the sand which adheres to it. The piece is then ready to be carried to the boring mill.

SECTION VI.

PROCEEDINGS IN THE CASTING OF BRASS CANNON.

The charge of the furnace consists commonly of old pieces of cannon unfit for service, of metals remaining from preceding castings, and of new copper. The size of this charge is proportioned to the moulds which are to be filled. The founder ought to know how much is necessary for the casting, including the waste.

The metals should be so placed in an air furnace that the most easy to melt may be least exposed to the fire and so that none may fall in a lump before the furnace is sufficiently heated to receive them without their hardening; otherwise the whole will form a cake in such a manner that it will be impossible to discover the bricks of the furnace to place them better; it then forms a thick crust which no fire can penetrate; the casting then fails. This accident should be more particularly avoided, as, besides the loss of the moulds, that of the furnace is also a consequence, of which there are many examples. But the founder ought to be acquainted with every part of his profession, and should also be able to construct his furnace with proper refractory earth for this purpose.

Everything being thus prepared the furnace is lighted, the fire of which should be carufelly attended; for too much activity in this element would produce the bad effects just mentioned.

The large pieces being in fusion, the new copper is put in. The founder attends to the proper time of putting in the fresh charges, and when the whole is melted the fire is increased to such a degree that all the heterogeneous particles are evaporated, which can only take place after an entire fusion.

A short time before the tin is put in the fused metal is scummed to clear it of the vitrified earths which float on the top. The proportion is 11 pounds of tin to 100 of copper; this completes the purification of the metal.

The floating vitrified particles are nothing but a metallic calx, which occasions loss by the particles of copper which it carries with it and which are afterwards detached from it.

In order to give a clearer idea of a casting, we will give an account of the operation.

Forty-four or forty-five thousand pounds of metal were put into an air furnace; of this about 40,000 pounds were old castings, and the rest new rosettes.[5]

The metal remained 20 or 21 hours in the furnace to acquire the quality proper for the casting.[6]

Half an hour before casting the pure tin of Cornwall was put in, and stirred with a long stick the better to mix it with the copper. Borings of brass guns were also used, and put in about three-quarters of an hour before casting.

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[5] The rosettes are masses obtained by cooling the surface of the melted copper by the application of a wet broom. The copper suddenly cooled hardens at the surface, and forms a broad thin cake, which is taken off. The broken surface of the rosettes is rough and the metal has not all the purity of which it is susceptible.

[6] A casting was made the 23rd of June, 1786, under the direction of Messrs. Poitevin and Douay. The charge of the furnace consisted of 33,130 pounds of old metal, 1,200 pounds of new copper, and 1,300 pounds of pure tin. The furnace was lit 25 hours before the casting, a time which appeared necessary, according to the principles of the founders, to obtain the best possible fusion of those metals.

The quantity of metal put into the furnace ought to be double the weight of the guns when completed. For example, these forty-four or forty-five thousand pounds were to make five 16 and two 8 pounders, which when completed were to weigh from twenty to twenty-three thousand; but it is necessary to consider the waste and the heavy spruces which are afterwards melted again in other castings.

When the metals were sufficiently melted, the casting was begun. For this purpose was suspended by its center a large wooden pole, with a long piece of iron at the end which was made red hot; this end entered a canal made at the bottom of the furnace. With this pole they drove in an iron stopper which closed the furnace at this place; the metal then ran through brick canals to the moulds. These canals were kept as hot as possible with coals till the moment of casting.

When several pieces are to be cast, all these canals communicate with each other; but the metal runs into but two moulds at a time. When the moulds are full, an iron plate, moved with a hook, is lowered. The metal then runs into new canals to fill other moulds, into which it falls as soon as two iron rods are raised, at the end of which an iron stopper closes the orifice by which the metal enters. The moulds are generally filled in four or five minutes.

The earth is removed from about the casting the day following. The mould is raised, the cannon and spruce cut off, and the cannon prepared for boring.

Section VII.

OF BORING CANNON.

Cannon were formerly cast hollow by means of a core covered with clay, which was placed in the middle of the mould, and kept in the center of the gun, at the bottom, by means of three iron rods which remained in the metal of the breech, so that when the core was taken off, there was nothing further necessary than to cleanse the bore of the gun with allezer. For this operation the gun was fixed vertically in a grooved frame, with its mouth downwards; the allezer's rod served as an axis to the machinery, which was made to turn by means of two horses, or other power, and the weight of the gun forced it down as fast as the allezer worked itself into the bore. The pressure occasioned by the weight of heavy pieces was modified by a counterpoise, as it would have been too powerful.

But the core, which formed the bore of the piece, was liable to become excentric, and would frequently occasion fissures, soufflures, by restraining the arrangement of the metal, so as to render the gun defective; cannon is, therefore, now generally cast solid, afterwards bored, and moulds are made without a core.

Maritz, an eminent founder at Strasbourg, is the first who thought of boring guns horizontally, and to give them a circular motion, instead of causing the cutters, forets, to turn. By this method cannon are easily bored to their axis, and you can ascertain that the bore is central when the rod of the cutter does not participate in the motion of the piece; whereas if the cutter was made to turn, and its direction not to coincide exactly with the axis of the piece, the gun might be bored off its center.

Formerly, and even now, in the ancient foundries, the operation was performed by using several cutters in succession until the gun was bored to its caliber; each cutter increasing the diameter of six or eight lines, after which the bore was cleansed and completed with the allezer. In the new foundries only one cutter is used. The bore is cut at first to its caliber, and then cleansed with the allezer.

The Plate 51 and their explanations are sufficient to indicate all the proceedings which are made use of in the new horizontal boring machine which is established at Chaillot, near Paris. It is put in motion by means of a steam engine; but there is nothing in the composition of the machine but what will also answer with any other mover, provided it is sufficiently powerful.[7]

While inspector of the artillery the author had an opportunity of witnessing the exertions made at Cecil furnace by Col. Samuel Hughes; at Washington by Henry Foxall; in Philadelphia; at Hope Furnace, in Providence, R. I.; Hanover Furnace, in Jersey, etc., by the persons who superintend these works, to improve even upon the European machines. It is but justice to declare that these horizontal boring machines have been carried by these gentlemen to great degree of perfection in the United States, and that out of upwards of 2,000 cannon of different calibers, which, in the discharge of his duty as inspector, he never was compelled to reject a gun on account of a defect in the bore, which was bored in their horizontal boring machines. (The Author.)

123. In summarizing the accomplishments of this century we find quite heavy guns being used for coast defense, most of them being muzzle-loading and smoothbore, however. A few were breech-loaders and a few were rifled. Plate 52 illustrates the advance made in the carriages. And this, after all, is the one and perhaps only significant respect in which one can expect to find coast artillery distinctive. The fact that one should notice even at this comparatively late date is that ships and fort carriages were still practically if not entirely the same. The real development that brought about such sharp distinctions comes in the following century, when events move so rapidly that one can hardly follow and determine the sources of the inspirations resulting in new designs, applications of new principles, etc.

124. *Nineteenth century cannon, 1800–1850.*—The quotation from Toussard's book on Artillery above gives a fair conception of the state of both the science of artillery and the art of making guns in 1800. During the following 50 years there is little indication of material advancement discernible in concrete results. The evidence is, however, that as with an individual who is preparing a treatise on any elaborate and complicated technical subject, everyone who had any concern with guns, gun carriages, and all forms or parts of equipment having to do with artillery was doing a tre-

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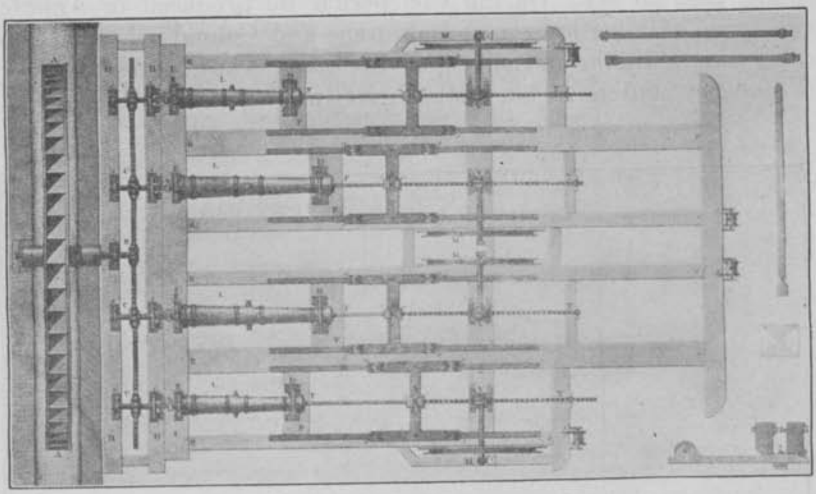
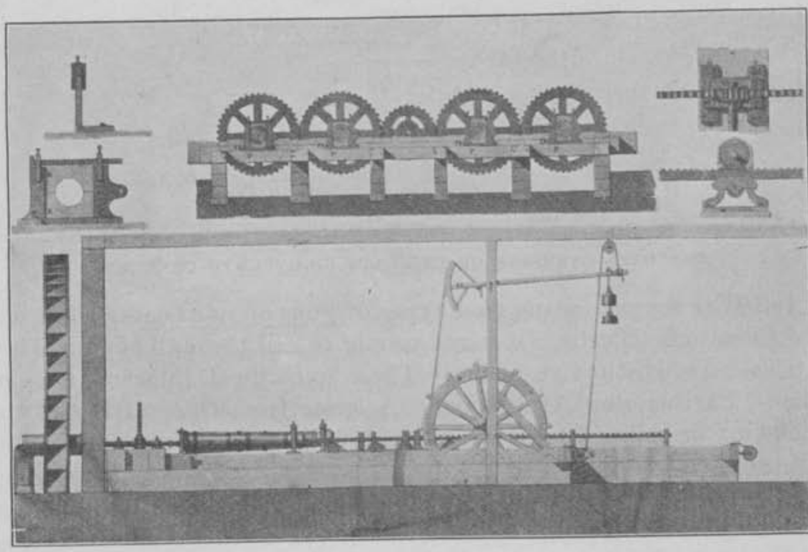
[7] This new machine was first invented at Strasbourg and greatly improved by Mr. Verbruggen, a Dutchman, who was chief founder at the royal foundry at Woolwich, where probably the best horizontal boring machine, in Europe, has been lately established; it bores both the inside, turns and polishes the outside at once. (Ch. James.)

PLATE 51.

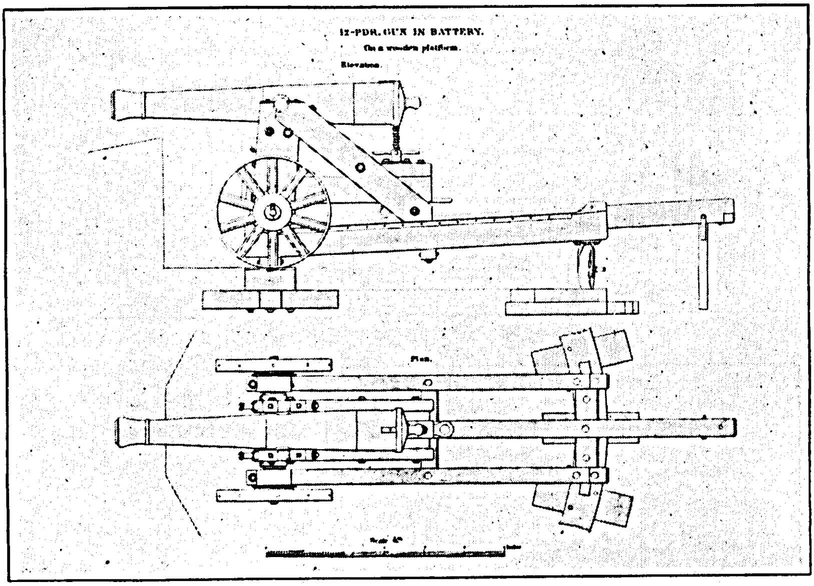




PLAN VIEW AND ELEVATION OF CANNON-BORING MACHINE.

mendous amount of thinking, putting together all of the discoveries and inventions of the past centuries, with the hopeful and determined desire to finally cease dabbling with the science and art and bring about a state wherein artillery might without stretching the imagination be considered a science, and the making of guns, carriages, etc., an art. During this period we produced in America two types of guns known as Dahlgrens and Columbiads that indicated some thinking in the proper direction. They represent merely a tendency and have but little merit in themselves. During our

PLATE 52.



SEACOAST CARRIAGE OF THE LATE EIGHTEENTH CENTURY.

Civil War we were using four types of guns on our boats and in our fortifications. Perhaps it is not proper to call them all types. They at least had distinctive names. These were the Dahlgrens, Columbiads, Parrots, and Armstrongs. A letter from General Lee to the chief of ordnance in Richmond in 1862 is very interesting in this respect:

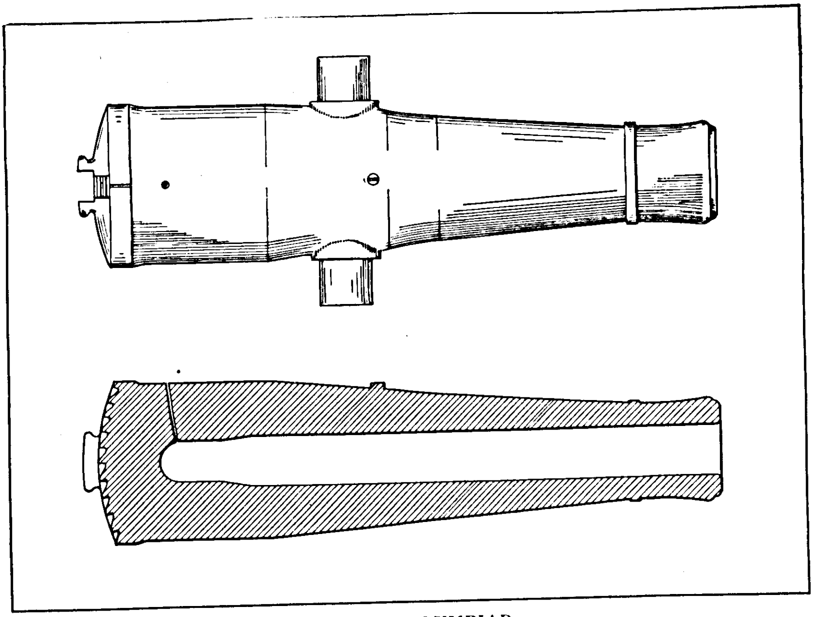
Col. J. Gorgas,
Chief of Ordnance Dept.

Colonel: Is there a possibility of constructing an iron-plated battery, mounting a heavy gun on trucks, the whole covered with iron, to move along the York River Railroad? Please see what can be done. See the Navy Department and officers. If a proper one can be got up at once, it will be of immense advantage to us. Have you got any mortars that we could put at some point on the railroad?

Very respectfully, R. E. Lee, *General.*

125. The Columbiad, Plate 53, was a heavy cast-iron smoothbore cannon of a form introduced by Col. George Bombord, and used in the war of 1812. Columbiads were made of 8 and 10-inch caliber and were used for projecting both solid shot and shell. They were equally suited to the defense of narrow channels and distant roadsteads. In 1860 General Rodman, of the United States Ordnance Department, devised a 15-inch Columbiad which was cast hollow and cooled from the interior, thus increasing the hardness and density of the metal next the bore. In this process of cooling General Rodman kept the exterior of the gun hot by special methods

PLATE 53.



10-INCH COLUMBIAD.

of heating and insulation to prevent radiation of heat. Both this and the Dahlgren were usually muzzle-loading although some few were modified to be breechloaders. The Parrot and Armstrong guns belong to the next period and will be described there.

126. The Dahlgren was a smoothbore cast-iron gun invented by Lieut. (afterwards Read Admiral) J. A. Dahlgren (born 1809, died 1870), of the United States Navy. Its principal peculiarities are the unbroken smoothness of its surface and the relation of its thickness at all points to the pressure in firing (determined by experimentation).

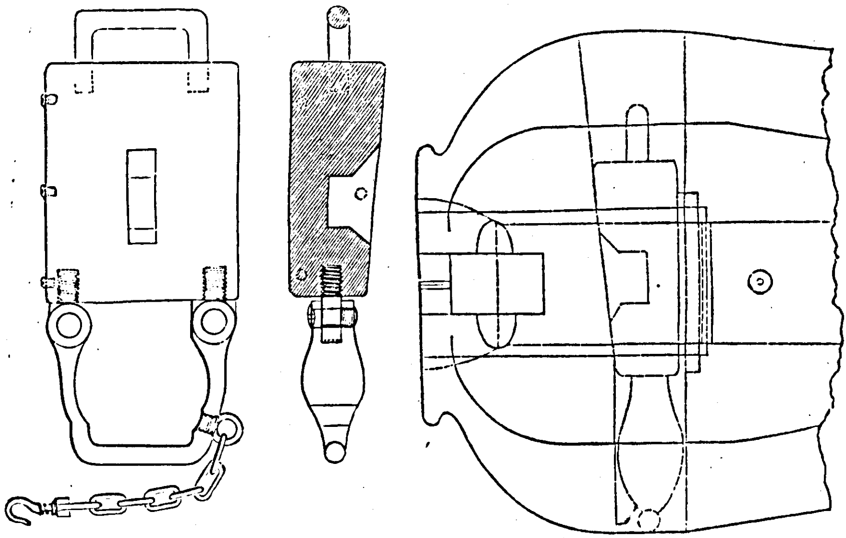
127. Following is some evidence indicating that at last designers and builders had come to the conclusion that smoothbore cannon and spherical shot must go forever: In 1845 Major Cavalli, a Sardinian officer, invented a new breech mechanism for a rifled gun of the

type shown in Plate 54. This mechanism was sufficiently successful to establish the rifled gun for good. To this was added the Wahrendorff gun, Plate 55, in 1846, and the results obtained from the two types were so promising, even though the weak cast iron of the gun gave way at the breech in several cases after the firing of only a few rounds, that experimenters and engineers of merit decided that the rifled cannon was the only weapon to consider.

128. In connection with the above it is interesting to quote from pages 74–78 of Sir James Emerson Tennent's book, The Story of the Guns:

It became evident that the imparting of new qualities to small arms must be fatal to the previous ascendency of cannon, and that

PLATE 54.



THE CAVALLI BREECH MECHANISM.

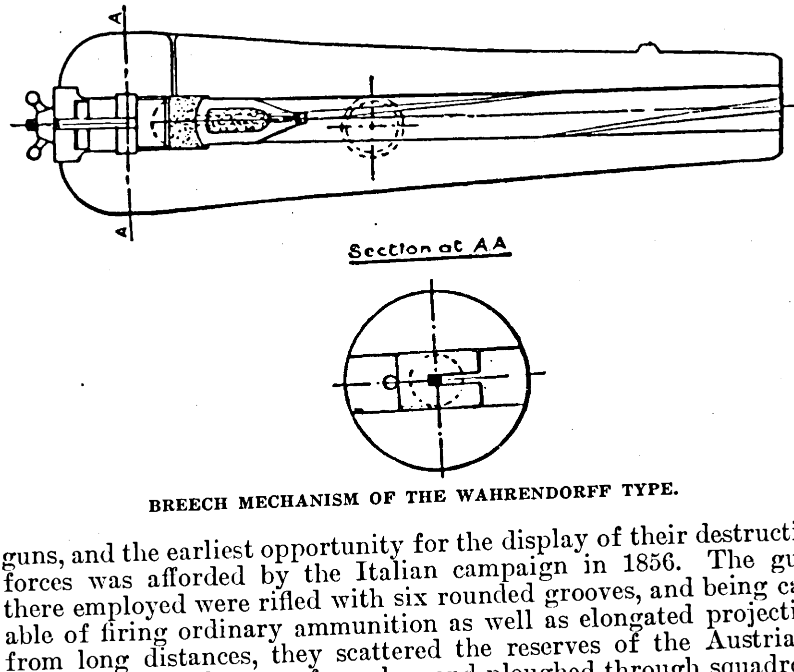
unless the power of the latter could be augmented in a like proportion, artillery would cease to exert its accustomed influence in deciding the fate of the battles. Out of this rational conviction arose the rifled guns of Lancaster and others in England, and in France the cannons rayees, whose powers of destruction, developed too late to be displayed against the Russians in the Crimea or the Baltic, were manifested with fearful effect at Magenta and Solferino.

The idea of rifling artillery was far from being new; it had been tried in Germany more than a century before our time, and Robins, the accomplished inventor of the "ballistic pendulum" for determining the relative velocity of projectiles, experimented on rifled field pieces in England so far back as 1745. M. Ponchara at Paris in 1819, and Montigny at Brussels in 1836, and again at St. Petersburg in 1836, had in succession renewed the attempt. Colonel Cavalli in Sardinia, and Baron Wahrendorf in Sweden, each carried

on experiments in rifling, and combined with it inventions for breech-loading; but the measure of their success was not attested by the practical adoption of any of their plans.

Colonel Treuille de Beaulieu made more than one effort between 1840 and 1852 to revive the subject in France, and at length, in 1854, Napoleon III, himself an authority on artillery, convinced by the protraction of the operations before Sebastopol of the insufficiency of smoothbore siege guns to meet the requirements of modern warfare, directed the resumption of experiments on rifled cannon. Uniting in one piece various suggestions of previous inventors, amongst others of Baron Wahrendorf and Lieutenant Engstroem, some brass guns were grooved under the direction of Colonel Treuille de Beaulieu, and sent for immediate service to Algeria. With further improvements, suggested by their trial there, and afterwards in Cochin China, France was the first to possess herself of rifled field

PLATE 55.



BREECH MECHANISM OF THE WAHRENDORFF TYPE.

guns, and the earliest opportunity for the display of their destructive forces was afforded by the Italian campaign in 1856. The guns there employed were rifled with six rounded grooves, and being capable of firing ordinary ammunition as well as elongated projectiles from long distances, they scattered the reserves of the Austrians, rolled back the charges of cavalry, and ploughed through squadrons at close quarters with case shot and canister.

This result was the signal for a reconstruction of all the artillery of Europe. Impressed with its importance, England was the first of the great powers to follow the lead of France, and so rapid was her advance upon it that specimens of her newly developed skill in the manufactory of rifled cannon, displayed at the Great Exhibition in London in 1862, called forth the unrestrained admiration of M. Treuille de Beaulieu, who acted as the commissioner of France. Fascinated by the beauty of the English guns, and passing the most cordial eulogium on the surpassing quality and splendor of their

workmanship, "un luxe et une puissance d'outillage merveilleux," he accompanied his phrase by the consoling reflection that although no examples of French artillery were exhibited in competition with those of Armstrong and Whitworth, still its paramount influence was apparent in these magnificent productions of its rivals.

129. In addition to the recognition of the merit of the principle of rifling, a most important and vital principle of the construction of cannon had been recognized rather early in the century. Cast cannon insisted on bursting no matter what precautions were taken. The full power of even the black powder that was then in use could not be utilized for fear of the failure of the guns. In America we adopted the principle of constructing our large guns in rather massive proportions, Columbiads, and of cast iron rather than of any malleable material. In 1854 Professor Treadwell, of Harvard University, presented a paper which was printed by the American Academy showing that a gun made of solid material soon reaches a limit of thickness beyond which additional thickness is practically useless in giving strength to resist tangential or circumferential stress. Here it is interesting to quote again from Tennent's book, pages 89–92:

Professor Treadwell, of the Harvard University in Massachusetts, working out the physical principles of the same problem as applied to artillery, has shown that it is impossible to increase the strength of cast-iron cannon, in any useful degree, by any increase to their thickness beyond that usually given to them, which, as a general rule, may be assumed to be equal to the calibre. To overcome this difficulty, Treadwell recommended that cast-iron guns should be encased with hoops of wrought iron, in layers placed one above the other, each with an increasing strain, so that the entire mass might oppose a combined resistance to the expansion occasioned by the explosive force of the gunpowder.[8] Like almost every other process recently applied to the improvement of ordnance, the idea of reinforcing guns by outward layers of wrought iron was not new. Colonel Treuille de Beaulieu states that it was proposed to the French Government by M. Goupil in 1833, and tried by Colonel Frederick shortly after in Belgium. The principle has also been applied in this country by Captain Blakely, of the Royal Artillery, who, in 1855, took out a patent for a "method of forming guns

[8] Treadwell's process is thus described by himself in a paper printed by the American Academy "On the practicability of constructing cannon of great calibre, capable of enduring long-continued use under full charges," page 19: "Now, to obviate the great cause of weakness arising from the conditions before recited, and to obtain as far as may be the strength of wrought iron instead of that of cast iron for cannon, I propose the following mode of construction. I propose to form a body for the gun, containing the calibre and breech as now formed of cast iron, but with walls of only about half the thickness of the diameter of the bore. Upon this body I place rings or hoops of wrought iron in one, two, or more layers. Every hoop is formed with a screw or thread upon its inside to fit to a corresponding screw or thread formed upon the body of the gun first, and afterwards upon each layer that is embraced by another layer. These hoops are made a little, say 1/1000th part of their diameters, less upon their insides than the parts that they enclose. They are then expanded by heat, and being turned on to their places, suffered to cool when they shrink and compress, first the body of the gun, and afterwards each successive layer all that it encloses. This compression must be made such, that when the gun is subjected to the greatest force, the body of the gun and the several layers of rings will be distended to the fracturing points at the same time, and thus take a portion of the strain up to its bearing capacity."

with an internal tube of cast iron or steel inclosed in a case of wrought iron or steel, heated and shrunk upon the cylinder." His specification explained that the substance of the patent consisted in rendering the internal diameters of the outer collars so much smaller than the external diameters of the inner ones that, after being cooled, the former maintain a uniform tension or permanent strain upon the latter. Captain Blakely's plan presents a remarkable analogy to the process of Treadwell, described in a previous page; but the patentee has stated before the ordnance committee of the House of Commons that between the two there is neither relation nor resemblance.

The first gun, however, which Captain Blakely produced in 1854 underwent a competitive trial with a cast-iron gun and a brass one, both in use in the service, in the course of which the cast-iron one gave way after 351 rounds, and the brass one after 479, whilst the Blakely stood 3,389 shots. Upwards of 400 guns on his plan have since been made in England, and "thousands," as the patentee states, in other countries, chiefly in France and the United States, where they were used in repelling the Federal attack upon Charlestown in the spring of 1863.

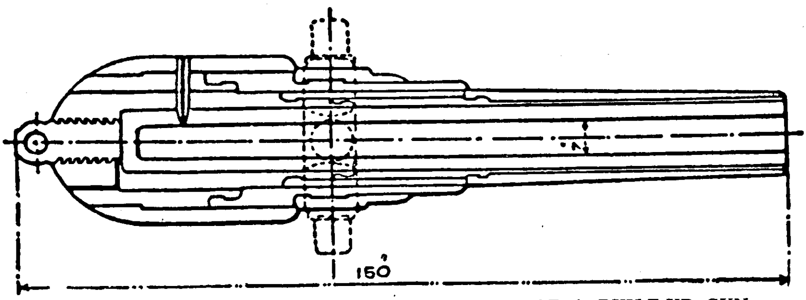
130. We see recognized finally in these 50 years the two principles which have permitted such amazing progress during the past 70 years; that is, from 1850 to 1920. Guns can not be made in one piece, and they must be rifled.

131. *Nineteenth century cannon, 1850–1900.*—With the two principles noted above recognized as fundamental, the stage was all set in 1850 for the most spectacular progress that the science of artillery and art of building guns have seen in their six and a half centuries of existence. At about this time Sir William Armstrong, who had deserted the profession of law for that of engineering, took up at his establishment experimental work on the development of rifled, built-up, steel and wrought iron, muzzle and breech loading cannon. In 1854 the British Government applied to a Mr. Joseph Whitworth, a precision instrument manufacturer of Manchester, for assistance in improving the Enfield rifle. In the course of his experiments to this end he worked likewise on cannon and developed a very unique if not entirely satisfactory system of rifling—that is, twisted oval and hexagonal bores.

Woolwich gun.—A built-up muzzle-loading cannon used in the British service. The tube was made of solid cast steel drawn out by heating and hammering (forged). After boring, turning, and chambering, the tube is heated to a uniform temperature and plunged into a covered tank of rape oil to harden and temper it. Wrought-iron coils are shrunk on over the tube to complete the structure. The breech coil is formed of a triple coil, a trunnion ring, and a double coil welded together. The muzzle coil is composed of two single coils united by an end weld. The breech piece is screwed into the breech coil so as to abut against the tube. The gun is

assembled by heating the coils, and these when expanded are slipped over the tube and allowed to contract. The tube is kept cool during this operation by forcing a stream of cold water through the bore. These guns have from 7 to 10 grooves semicircular in cross section with curved edges and with a uniformly increasing twist. It was a practice to heat the tubes to a red heat and immerse them in rape oil without any subsequent tempering. The natural result in many instances was the bursting of the gun. This caused a distrust of steel until the proper methods of working such metal were developed in about 1880. The steel barrels of the muzzle-loading rifles were forged solid, while the tubes of the breech-loading guns were forged either solid or over a mandril. In building on the hoops the scheme was developed of locking them together, Plate 56. This scheme is still followed by some countries, by ourselves to a certain extent, but is avoided entirely by others who prefer to let the hoops part if the tube lengthens.

PLATE 56.



METHOD OF LOCKING TOGETHER THE HOOPS OF A BUILT-UP GUN.

133. In 1863 England conducted an investigation of the various guns that had been developed, and adopted as the approved piece of ordnance the built-up steel and wrought-iron muzzle-loading rifle rifled with a number of wide, deep grooves. This was for them an unfortunate step backward, and they did not reverse this decision until about 1880. Meanwhile Armstrong continued to manufacture breech as well as muzzle-loading rifles, and sold many of both kinds to both the Union and Confederate Governments in America during the Civil War. The muzzle-loading rifles required a projectile provided with studs, or in some cases with gas-check pads of copper cut to fit the rifling. Such projectiles were found to fly more accurately and to a greater range.

134. During the years 1850–1870 General Rodman, of the Ordnance Department, was experimenting on the production of a cast-iron gun by the method of chilling the surface of the bore by means of water in a hollow core, while the outside was kept hot both by heating and by insulating. This procedure produced a gun whose

inner layers were under considerable contraction and they were much superior to the unchilled cast guns. A large number of cast guns were made over this procedure, one with a caliber as great as 20 inches. The quality of the iron was quite superior and this may have had a little to do with the quality of the gun. Most of the guns were muzzle-loading and smoothbore, but a number were tubed with wrought-iron tubes which were afterwards rifled. Some were rifled with two or four broad, deep grooves, and some were converted into breech-loading rifles. Rodman guns were of the Columbiad design, but were cast over Rodman's scheme of chilling. This was merely a temporary development, however, and could not endure because, although it produced a gun in which the inner layers were under compression, the material used had not sufficient strength to withstand the pressures developed in a high-power rifle.

135. We do not have any such guns in service in America to-day. During the World War, however, the French used many guns of large caliber which were made of cast iron and either tubed with steel throughout their length or for a short distance from the powder chamber. Among these are the 190, 240, 270, 293, 305, and 320 millimeter howitzers and mortars mounted on railway carriages. Many of these guns were used by American artillerymen, and although several of the guns burst, in general they rendered most excellent service. One 320-millimeter howitzer examined had fired 1,500 rounds and the rifling was still in such good condition as to indicate a probable remaining life of 500 rounds. This information is not given as a recommendation for the manufacture and use of cast guns, but to make a matter of record the fact that such guns took their part along with the more modern steel built-up and wire-wound guns in the greatest struggle the world has known. *When a war overtakes any nation it is too late to build large guns. They must get along on the large caliber guns they possess, or can buy;* hence the use by the French of every large gun they could find.

136. In about 1880 commercial steel manufacturers in America began to acquire forging facilities that permitted them to manufacture the parts for guns of large caliber. At the present time our facilities of this description are second to those of no other nation. In fact, we are the great iron producers and fabricators of the world now and whatever we wish can be made with relative ease. By the year 1900 all of the principles over which the guns of to-day are constructed were rather well known. As soon as the art of constructing guns of a number of pieces had been well developed, the metallurgist was called upon for still better materials. Thus, in 1900 we had built-up and wire-wound guns of alloy steel that were capable of withstanding pressure as great as 40,000 pounds per square inch. All of these guns were breech-loading, using a screw breechblock

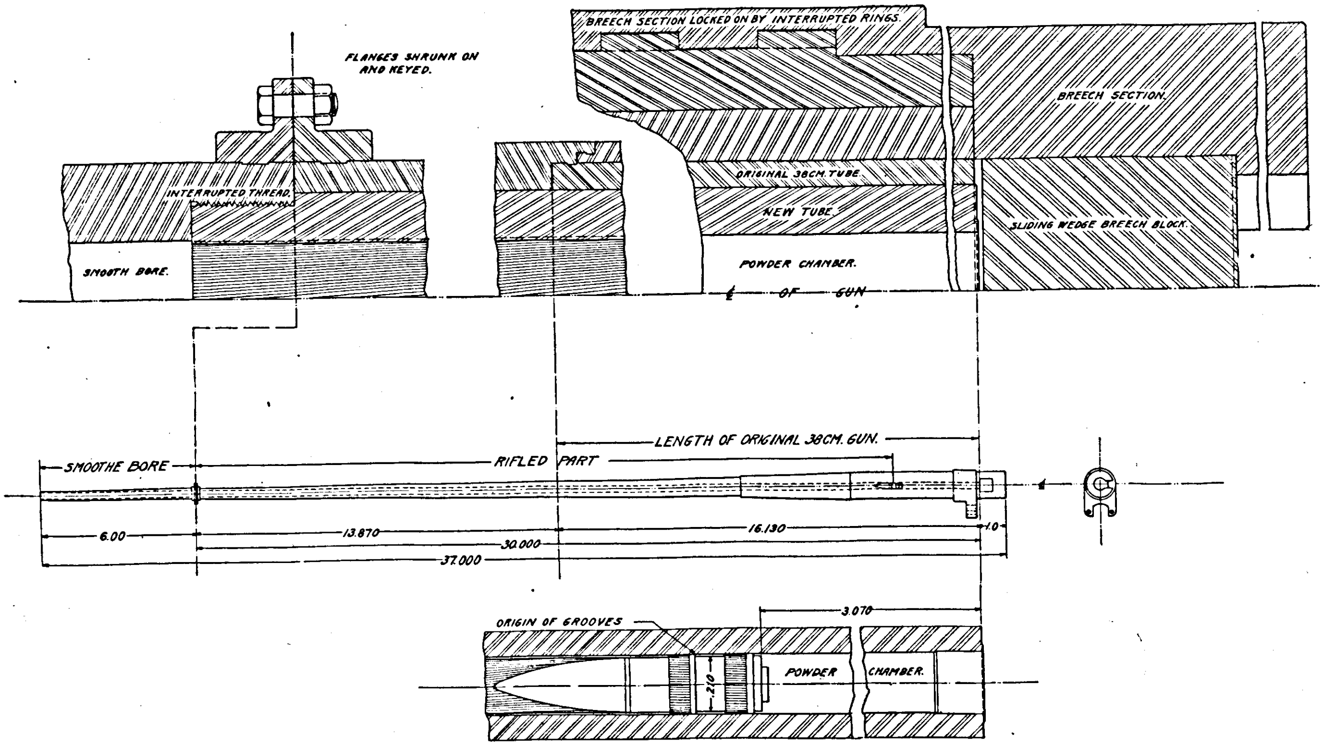
having an interrupted thread that permitted it to be locked or released by rotating through from 30 degrees to 45 degrees, and were rifled with a large number of comparatively shallow grooves—that is, not more than one-eighth of an inch deep, and not more than one-quarter of an inch wide. Both uniform and increasing twist rifling was used, and even to-day we find both systems used.

137. During the past few years the Ordnance Department has developed a 50-caliber 16-inch gun for American coast defences that is probably the most powerful weapon of its kind now in existence. It therefore represents the limit of the development begun in about 1250. This gun is made partially over the built-up principle, is wire wound, is made of the finest of alloy steels, and the parts were forged in the ordnance department of our Bethlehem and Midvale Steel Co.'s mills. The machine work has been done at our Watervliet Arsenal. Some of the guns have been proved and found quite satisfactory and are now being installed. This gun and its carriage will be described in detail in the next section. This gun is capable of firing a 2,400-pound projectile to a range of 29 miles. It is the temporary conclusion that this gun is probably of the economic maximum size. Experimental guns of 18-inch caliber are being considered, but it is not yet certain that there is a definite need for them. As far as the construction of the guns is concerned, the principles evolved from 1850 to 1860 are still being followed. Methods of manufacture have been tremendously refined. There is yet considerable work to be done in developing the proper rifling, and in studying the form and proportions of the powder chamber and main bore much research work is also necessary.

138. The achievements of the nineteenth century, in summary, comprise a recognition of the two fundamental principles of rifling and multiple piece construction, and the development of the art of constructing rifles of wrought iron, carbon steel, and finally of alloy steel. Rifling was modified from several wide and deep grooves to many narrow, shallow grooves. Breech mechanisms were perfected to the point of actually preventing the escape of gases to the rear. Dahlgren, Columbiad, Parrot, Whitworth, and Rodman guns were developed, served for a time, and passed from favor and service. The weight of guns increased from a maximum of 15 tons to 100 tons. Muzzle velocities increased from 1,500 to 3,000 feet per second. Black powder passed and smokeless powder came into use. High-explosive and armor-piercing projectiles were developed, and finally the methods of rotating projectiles were so improved through the final adoption of wide copper bands at the rear of the projectile as to secure real accuracy of fire.

139. *Twentieth century cannon.*—The only cannon that will be mentioned under this heading is the long-range gun, Plate 57, developed by the Germans and used by them in shelling Paris in

PLATE 57.



THE SO-CALLED "GERMAN LONG RANGE GUN."

1918. This cannon had the characteristics of abnormal length and used a projectile grooved to fit the rifling of the gun. They were probably made by retubing worn 381-millimeter 45-caliber naval guns to a diameter of 210 millimeters and length of about 140 calibers. It is not yet known what powder was used nor in what form the powder charge was made up. A muzzle velocity of about 5,200 feet per second was developed which carried a 264-pound projectile, Plate 20, to a range of 76 miles. The elevation of the gun for this firing was about 54 degrees and the projectile mounted to a maximum height of about 24 miles in traversing the trajectory of 90 miles between the gun located in the Forest of St. Gobain, near Laon, France, and Paris, the target. About three minutes were required for the projectile to travel this distance.

140. It is believed that the gun tube was made of unusually good alloy steel. It was necessary to use a grooved or rifled projectile because the shearing strength of copper is not such as to permit its use for rotating bands. The use of a grooved projectile resulted in such tremendous friction and rapid wear that the life of the gun was about 50 rounds. The firing of a projectile at such a tremendous velocity required the accurate balancing of the projectiles on a dynamic balancing machine, because unbalanced projectiles would have deviated widely from the mark in so great a distance.

141. This development comprises the construction of a 140-caliber gun, the use of a rifled projectile, the attainment of a muzzle velocity of 5,200 feet per second, and the discovery that maximum ranges are attained at elevations as high as 55 degrees. Other discoveries were made with reference to the regulation of the rate of burning of powder that have not yet been revealed.

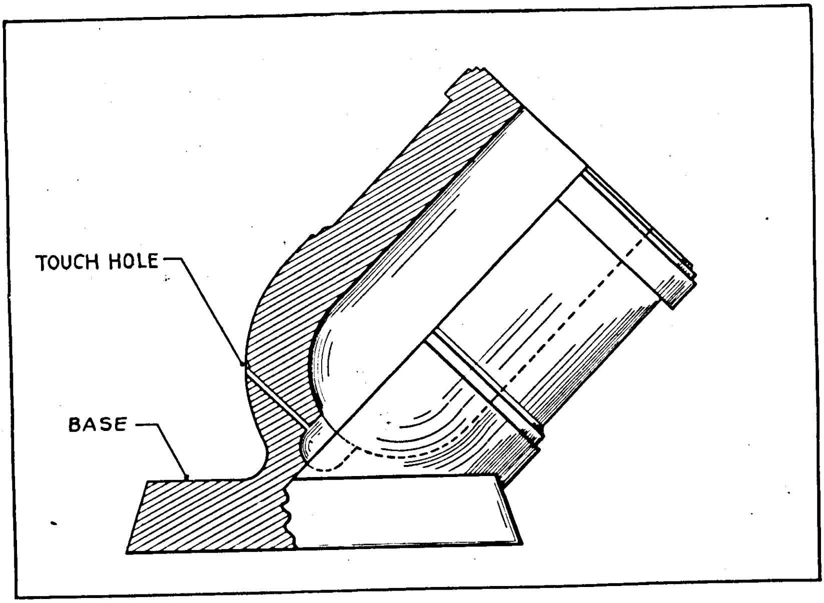
142. *Unsolved problems.*—Among the known unsolved problems with which we are confronted to-day are the four very important ones concerning the causes, character, rate, and effect of the wear of guns. If we knew all of the causes we might avoid injurious practices and improve construction. If we knew more about the character, the various types, we might the more easily run down the causes. If we knew more of the rate, we would be the better able to determine what practice to follow in determining replacements and the materials that might more properly be used. If we knew the effects of the various characters of wear, we would then be able to judge from examination in the field as well as in our fortifications just when a gun becomes practically useless.

GUN CARRIAGES.

143. When guns were first made, between 1250 and 1300, it was not uncommon to find them used in the field by simply placing them on a mound of earth with a stake at the rear to check the recoil.

Later in the thirteenth century the practice of strapping the smaller guns to beams of wood was started, and in such cases a stop was provided at the rear of the beam to prevent the gun from slipping from the straps. This beam on which the guns were first mounted received the name of a cradle, and ever since that time we have been using the term cradle to indicate that part of a gun carriage which supports the gun tube. During the fourteenth century—that is, from 1300 to 1400—we find the crudely shaped mortars which in some cases were provided with a screw at the rear, or perhaps merely a projecting spike which was screwed or driven into a hole chiseled in a heavy beam of wood. Such a mortar mount-

PLATE 58.



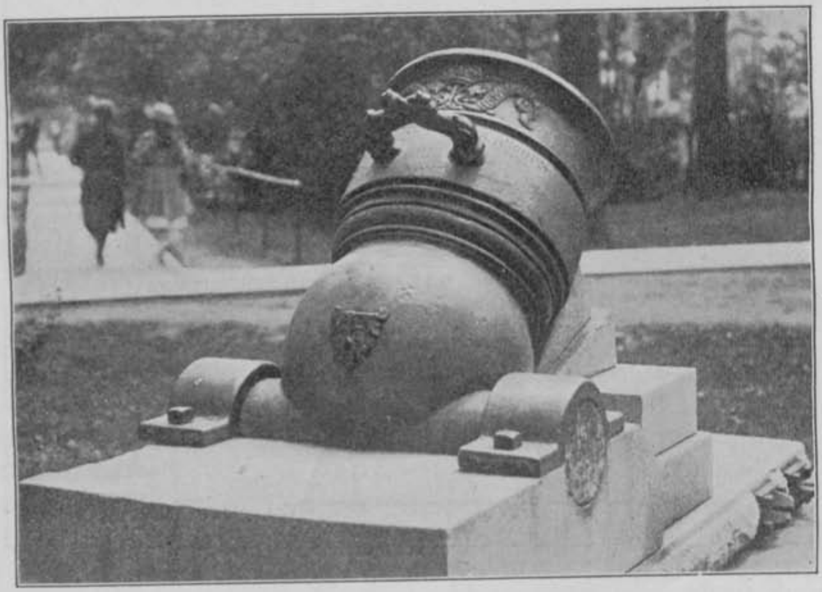
EPROUVETTE MORTAR.

ing is shown in Plate 7. The term mortar used strictly implies a very short cannon cast integral with its base, Plate 58, and set at an elevation of 45 degrees with the base. The range was varied by varying the powder charge. In other cases the mortar was simply shaped like a sphere and was set in a spherical hole in a wood beam. This shape was later modified in the case of mortars to include trunnions, one element of the surface of which was tangent to the rear of the spherical breech of the mortar. The mortar shown in Plate 59, although cast in 1724, is of this fourteenth and fifteenth century design, and the trunnions represent approximately a cylinder, a given portion of which is to the rear of the spherical breech of the mortar. The carriage of such mortars was still simply a built-up

platform of timber reinforced perhaps with rods or bolts of wrought iron and provided with the necessary rings, clips, and hooks for manipulation of the ropes.

144. The heavy guns developed between 1300 and 1400, among which are the 25-inch caliber wrought-iron guns that have been discussed in paragraph 107, were of such weight that in general they were simply mounted on platforms of planks or on mounds of earth. Later wheeled carriages, such as is shown in Figure 6, Plate 40, were developed for some of these guns. The guns were not originally provided with trunnions, however, and they did not lend themselves to mounting on carriages of this type. In this same century wheeled carriages such as are shown in Figures 1 and 2, Plate

PLATE 59.



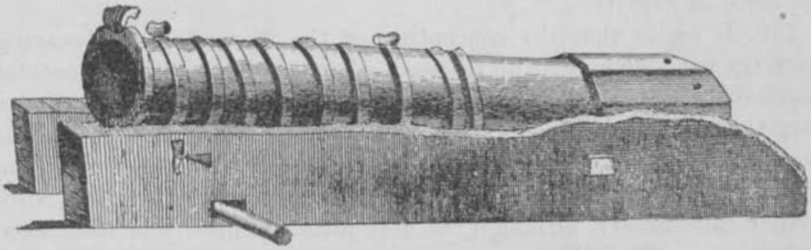
BRONZE MORTAR OF THE SIXTEENTH CENTURY.

40, were developed; it is interesting to note how closely these early designers of carriages approximated the design that we find in general use to-day. For field use the typical carriage was that shown in Plate 60. The carriages first developed for ship and fortification use were either two or four wheeled trucks similar to that shown in Plate 47.

145. Carriages for use on ships and in fortifications were common in design until the nineteenth century, when the increasing accuracy of small arms and the slightly increased accuracy of the cannon themselves compelled the construction of good placements with protecting walls in front with embrasures through which the

guns might be fired. The carriages for use in the field as well as for use in fortifications had undergone some changes to the extent of being made partially of iron and being provided with a screw under the breech end of the gun to elevate and depress it instead of the original wedge; but in the matter of design as to

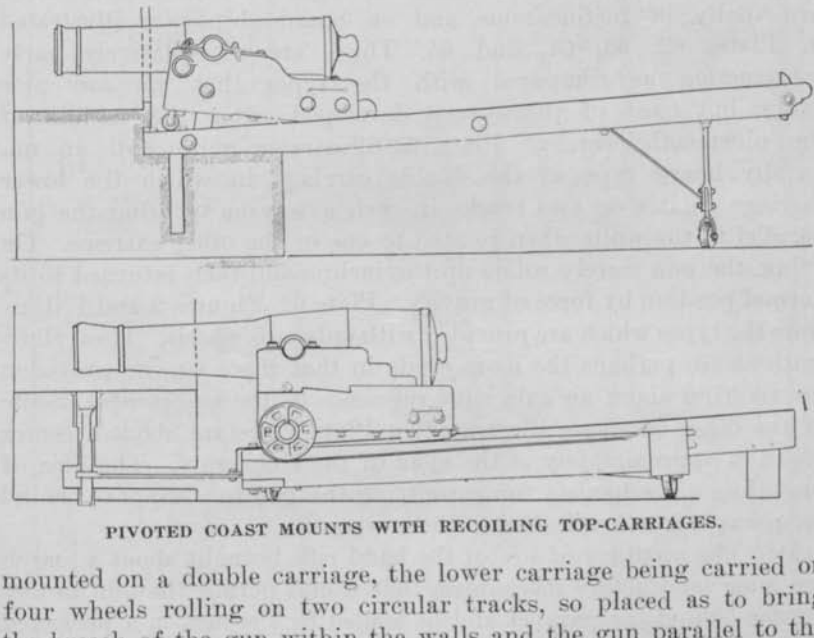
PLATE 60.



CRUDE CARRIAGE OF THE FOURTEENTH CENTURY.

shape and refinement little had been done. In the nineteenth century we find further developments in carriage design such as are shown in Plate 61. These embodied the mounting of the gun carriage in such a way as to be pivoted around a center under the apex of the embrasure in the wall. In other cases the gun was

PLATE 61.



PIVOTED COAST MOUNTS WITH RECOILING TOP-CARRIAGES.

mounted on a double carriage, the lower carriage being carried on four wheels rolling on two circular tracks, so placed as to bring the breech of the gun within the walls and the gun parallel to the walls when turned entirely to one side. The top carried in such cases was simply the carriage shown in Plate 47 refined as to elevat-

ing mechanism, perhaps, and made partially of iron. The tendency toward double carriages became more pronounced as the necessity for protecting the gunners was appreciated, and we soon see the evidence of a search for a satisfactory type of disappearing carriage. In general we find in the case of a double carriage that the top carriage rolls up an incline and returns to its normal position by force of gravity.

146. It seems that the conception of the idea of a disappearing carriage came about during the time when the range and accuracy of small arms was such as to be of prime concern to the gunners of even large cannon. As long as small arms could be used to pick off the crew of a battery, some steps had to be taken to protect these men. The scheme of firing through an embrasure in a wall was not altogether satisfactory, although we find forts designed and built even as late as our Civil War arranged in a series of floors with the cannon as close together as possible on each floor. Thus Fort Sumter, which was the first to be taken in the Civil War, was a masonry structure several stories high and bristled with cannon projecting from embrasures quite close together and on all floors. Old fortifications of this type which are out of date during only the last 60 years can be found in almost any port of any size in America or in Europe.

147. A large number of metal carriages of various types used principally in fortifications and on board ships are illustrated in Plates 62, 63, 64, and 65. These are of relatively early construction as compared with the types that we are now using, but most of them were developed after the middle of the nineteenth century. Plate 62 illustrates quite well an unusually heavy type of the double carriage in which the lower carriage rotates on two tracks in such a way as to bring the gun parallel to the walls when rotated to one or the other extreme. On firing, the gun merely rolled up the incline and then returned to its normal position by force of gravity. Plate 62, Figures 2 and 4, illustrate the types which are provided with only two wheels. These illustrations are perhaps the more crude in that there was no provision for rotating about an axis with reference to the embrasure. Some of the other carriages illustrated in Plate 62 rotate about a center which is approximately at the apex of the embrasure. The idea of providing a mechanism for permitting the gun to disappear behind the parapet is not embodied in these types.

148. The accuracy of fire of the hand rifle brought about a search for some satisfactory mechanism that would permit the gun to disappear behind the parapet and be loaded by the men in a protected position. Plate 63 represents the earlier models or designs for the accomplishment of this aim. Some of these were for use in the field and others for use in fortifications. It would appear that they were

PLATE 62.

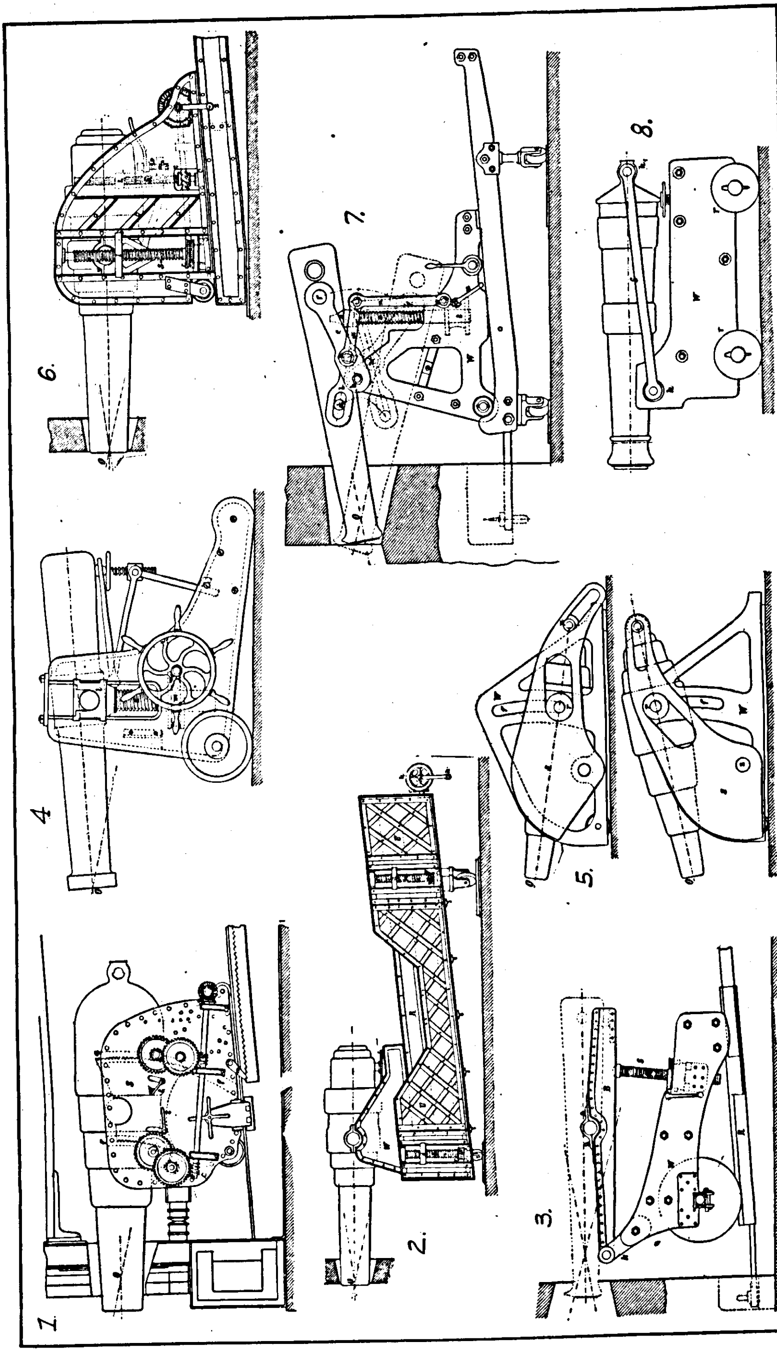


PLATE OF EARLY SEACOAST AND DISAPPEARING CARRIAGES.

PLATE 63.

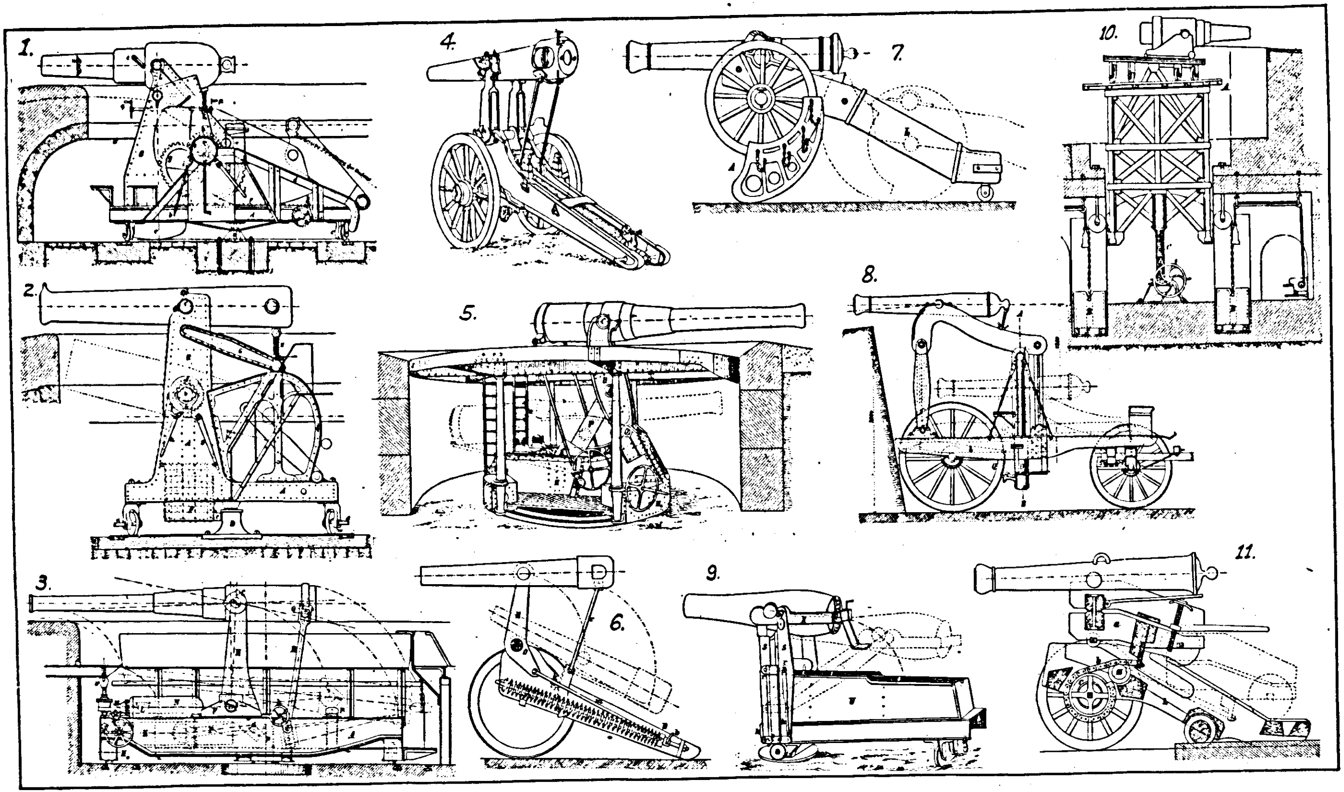


PLATE OF EARLY SEACOAST AND DISAPPEARING CARRIAGES.

PLATE 64.

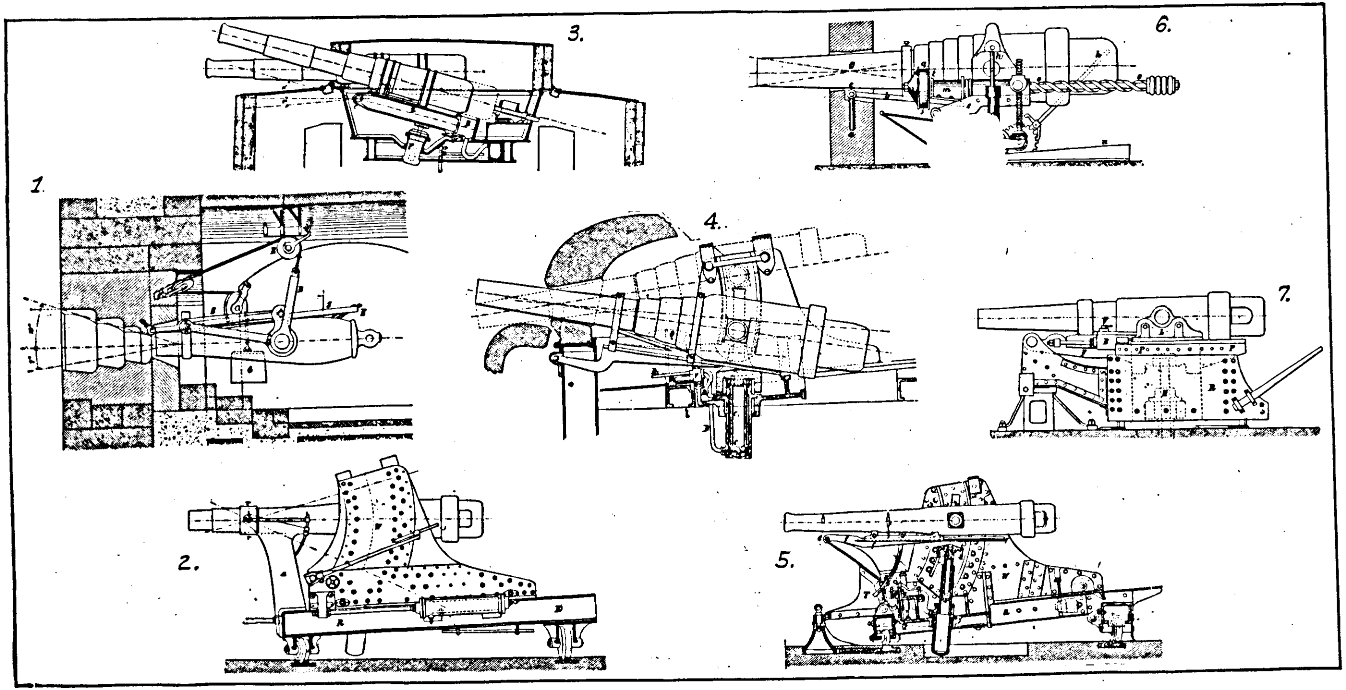


PLATE OF EARLY SEACOAST AND DISAPPEARING CARRIAGES.

PLATE 65.

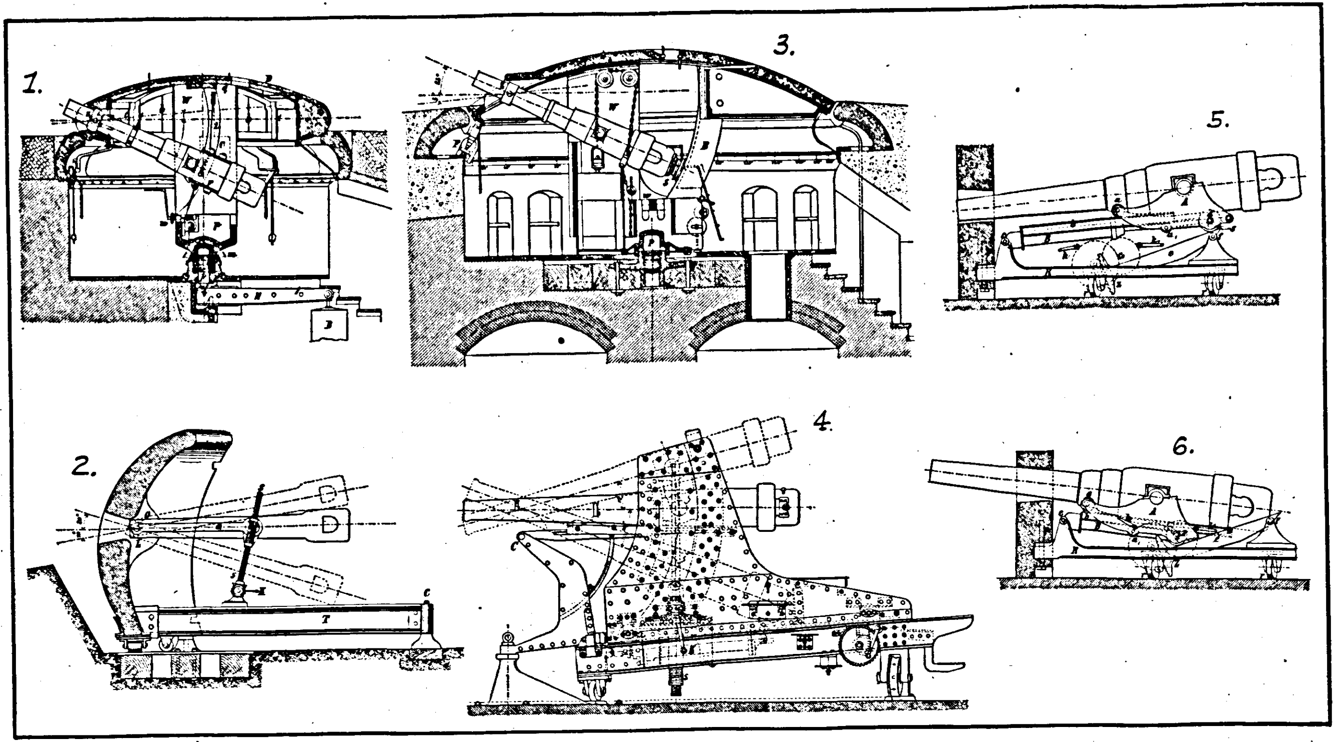


PLATE OF EARLY SEACOAST AND DISAPPEARING CARRIAGES.

satisfactory for use at the time when they were constructed, although they seem quite crude now.

149. *Disappearing carriages.*—The construction shown in Plates 63 and 64 is the forerunner of the scheme developed so elaborately for use in American fortifications between 1880 and 1914. It will be seen in Figure 5, Plate 63, that the gun is here mounted on a double carriage, the lower of which can be rotated to place the gun in azimuth. As the gun is fired from a carriage of this type the force of recoil raises the weight in the well at the front. When the gun or top carriage is at its lowest position, it is automatically locked by a latch so that the gun may be loaded in a protected position. When the gun

PLATE 66.

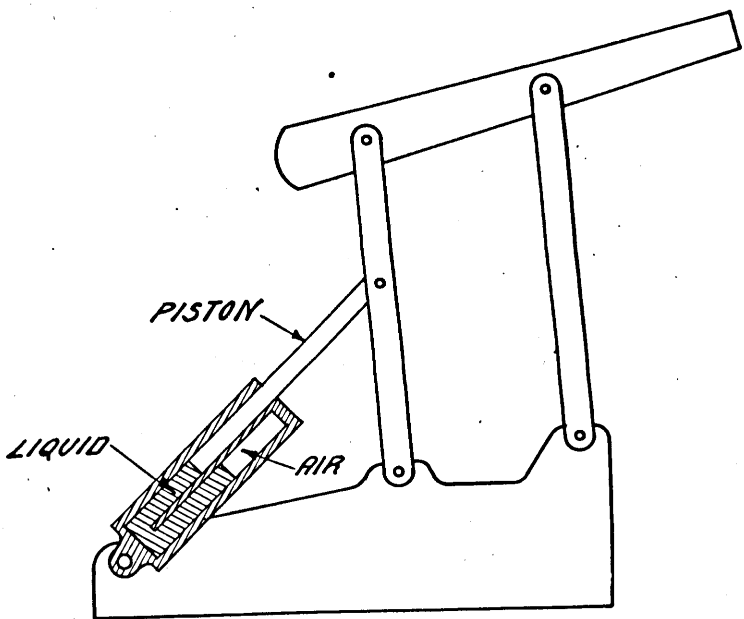


DIAGRAM SHOWING PRINCIPLE OF THE EARLY HYDRAULIC BRAKE.

has been loaded and is ready to fire, the latch is released and the weight pulls the carriage up to the firing position. The use of such a weight as this to elevate the gun into its firing position is characteristic of the American Buffington-Crozier disappearing carriage; other types shown in these plates check the recoil of the gun or top carriage by the use of levers, friction or springs.

150. The next feature to be added to the disappearing carriage was the relatively crude hydraulic brake of a design shown in Plate 66. This brake is a forerunner of a recuperator now used on many British, French, and American field carriages. With the British carriages the liquid comes directly into contact with the air, while in

most American and French types a piston is interposed between the liquid and the air.

151. The Crozier disappearing carriage, which has been developed in America to such a high degree, is illustrated in Plate 168. This is perhaps the limit of development in disappearing carriages, and it is now passing into disuse because of the impossibility of providing the gun with sufficient elevation with this type of mechanism. The weight shown in the well is attached to the lower end of the gun lever which support the gun. These gun levers are pivoted on a top carriage which rolls on horizontal surfaces or guides. The lower end of the gun levers are compelled to move in vertical guides so that as the gun recoils the central pivots move in a horizontal line, while the connection between the lower end of the levers and the weight move in a vertical line. The top carriage to which the central pivots of the levers are attached is provided with hydraulic brake cylinders, the purpose of which is to check the recoil of the gun. When the horizontal top carriage has reached its rear position the gun has dropped to the position shown by the dotted line and is in a convenient loading position as well as being entirely behind the parapet. The two levers seen at the rear of the gun are known as the elevating arms, and are attached at their lower end to a nut on a screw by which the elevating arms and the rear of the gun can be moved up or down.

152. Since we would not think of constructing a carriage to-day with an elevation of less than 45 degrees, such carriages have necessarily been discarded. An elevation of as much as 30 degrees has been secured recently in one such carriage especially redesigned for one of our latest 16-inch 50-caliber guns. To a certain extent the mounting of such a gun on this limited elevation carriage may be considered a waste of the possibilities of the gun, because its range can be considerably increased between 30 degrees and 50 degrees. A comparison of this carriage with the other characteristic type of carriage—that is, the barbette—shown in Plate 162, gives one a realization of the vast difference in the sizes and the probable difficulties in maintenance. When this carriage was first made, the maximum elevation provided for the gun was 15 degrees, because at this elevation it was thought that the maximum practicable range was being secured. This sounds rather absurd now, because elevations of 45 degrees are quite the rule. Since at the time of the construction of such carriages guns were in general in quite plain view of the ships against which they were firing, it was considered most desirable to protect the gun carriage and crew against shell fire from sea. The carriages were therefore mounted behind parapets, and when the gun was at its lowest position in recoil it was supposed to be below

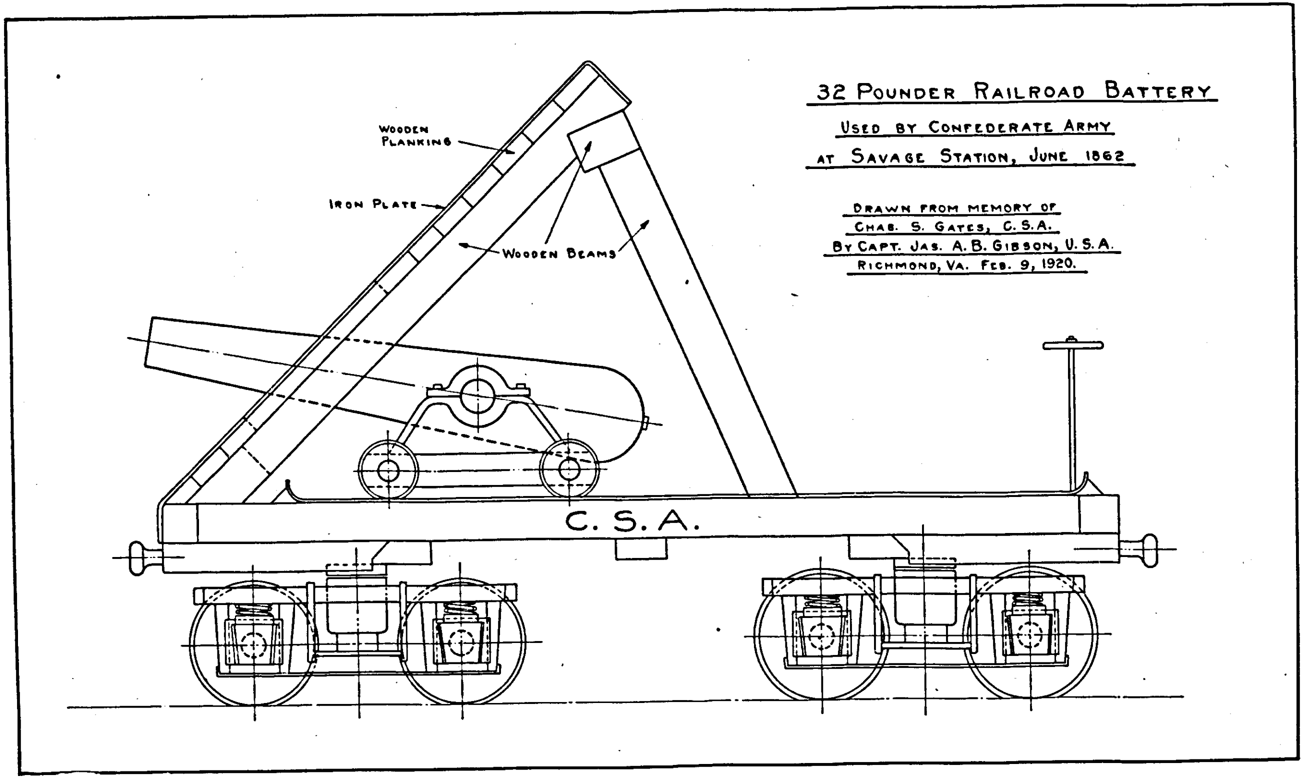
a 7-degree depression angle over the edge of the parapet. Any object under this line was supposed to be safe from fire from sea.

153. *Barbette carriages.*—At the same time that so much attention was being put to the devising of carriages that would permit of the disappearance of the gun behind a parapet, the development was continuing on other types that permitted the gun to remain always in sight over the parapet. Those designs of carriages shown in Plate 64 which maintain the gun always in view over the parapet were and are still termed barbette carriages. Under this heading come the pedestal carriages, Plate 64, very commonly used on board ship as well as in fortifications, especially for small and medium caliber guns. For larger caliber guns a modification of this type is used, which has been developed between the period of 1860 and the present time to the carriage that has just been completed for the 16-inch 50-caliber gun. This carriage presupposes the mounting of the gun in a cylinder which in turn is carried by means of its trunnions on the side frames of the chassis of the main carriage. The gun is thus free to slide in the direction of its axis in the cylinder or cradle, the cradle is free to rotate about a horizontal axis, and the chassis is free to rotate on a base about a vertical axis. When the gun is fired the recoil of the gun in the cylinder or cradle is brought to a stop through the use of a hydraulic recoil mechanism and is returned to its original position either by means of springs or a pneumatic recuperator. In the case of such carriages it is necessary to lower the gun from its firing position to some predetermined loading angle and then elevate it again to the firing position with each charge. This is distinctive of this type of carriage as against the scheme of the disappearing carriage, where the gun recoils to its loading position and as soon as it is loaded and released returns automatically to the firing position.

154. *Mortar carriages.*—A third type of carriage, if we may call it a distinctive type, is that for mortars, Plate 210. Since mortars have generally been mounted in pits, it probably is improper to style the carriages on which they are mounted barbette carriages, although they do not differ materially from barbette carriages in construction. The carriage shown in Plate 210 is one of the earliest provided for our own 12-inch mortars, and as the gun is fired it recoils about the axis of the elevating arms pivoted to the racer under the muzzle of the gun. The recoil cylinder is mounted between the elevating arms in a manner similar to those first used, Plate 66, and serves to check the recoil of the gun while springs under the forward arms return the gun to its normal position.

155. *Railway carriages.*—In our Civil War in 1862 General Lee found it desirable to mount some guns on railway flat cars. This

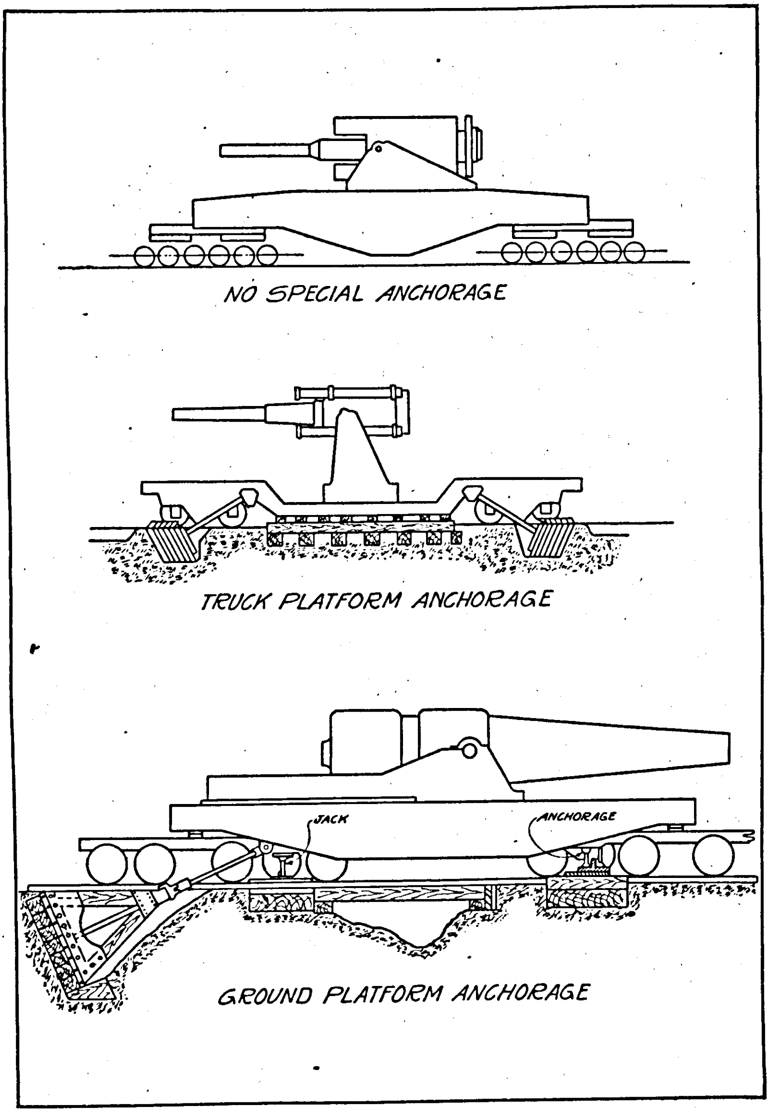
PLATE 67.



GENERAL LEE'S RAILWAY MONITOR.

design is shown in Plate 67. In all wars it has been found that the heavier guns have been so difficult to move that until the recent war the heavier guns employed on our ships and in our fortifications were very little used in any field warfare. Between 1862 and 1914 the British, French, German, and American Governments had done a little in the development of railway carriages for the heavier guns, but in comparison with the progress that has been made since 1914, one would say that little had been accomplished. In 1914 the French Government concluded that the guns in their fortifications as well as those on some of their ships would render better service if mounted in some way so as to be useful in the field. During the period 1914–1918, therefore, the four principal countries involved in the conflict spent a great deal of their energy in the development of carriages that would enable them to use even their 15-inch and 16-inch guns in the field. When such carriages were first made the possibility of their use for coast defenses was seen, but the pressing need was for use in the field, and their use in coast defense was purely incidental. Under the pressure of shortage of manufacturing facilities some types of railway carriages have been developed which are not of the maximum universal usefulness and their value in coast defenses is perhaps questionable. The types developed are shown in Plate 68. These include the "sliding" type carriage, where the gun is mounted simply by means of its own trunnions on the side girders of an extremely heavy steel railway carriage. The "emplacement" type involves the mounting of the gun in a cradle, which in turn is suspended by its trunnions on the side girders of a railway carriage. The sliding type just mentioned is fired directly from the track on which the gun is transported. When the gun is fired heavy beams mounted in the bottom of the carriage slide on steel eyebeams attached to the railway ties. For the emplacement type of carriage a pit is dug and a heavy timber or steel foundation or firing platform is placed under the track. The mount is then placed on this position and the trucks removed. When the gun is fired the force of recoil is transmitted directly through the emplacement into the ground. A third type, known as the outrigger type, does not involve any subtrack foundation, but transmits the force of recoil through the struts of the outriggers into the heavy timber pads and thence into the earth. The last type, which is quite similar to the sliding type, involves the mounting of the gun in a cradle, which in turn is supported by means of its own trunnions on the side girder of the carriage. When the gun is fired the entire carriage rolls back on its wheels and is stopped by the friction of the brakes. This is termed a "rolling" carriage. The railway carriages of the subtrack and simple track platform types have been considered of value for coast defense purposes and are in-

PLATE 68.



RAILWAY CARRIAGES.

cluded among our coast defense weapons. It is not certain whether the sliding and rolling types can be used to advantage.

156. The latest carriage of these types that has been designed takes a 14-inch 50-caliber gun and apparently embodies all of the requirements which usually govern the design of a barbette carriage. It is thought, therefore, that it will prove as satisfactory as the barbette carriage, and it has the advantage of making the gun mounted on it available at any place along the coast where the simple type of platform required has been installed. This type of carriage seems to offer considerable promise of development, if we may consider the 14-inch 50-caliber an adequate weapon for our coast defense. Unfortunately railway clearances are so limited by tunnels, bridges, platforms, etc., already constructed that it does not seem possible to mount satisfactorily a 16-inch gun on such a carriage. For further discussion of railway carriages the reader is referred to Railway Artillery, particulaly Volume I.

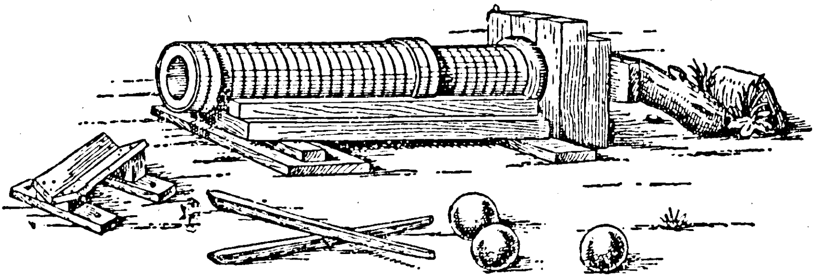
157. In summary of carriages we have seen the development proceed from the crude plank cradle through the wheeled mounts of the fourteenth century, the truck mounts of the period from 1500 to 1800, the double carriage and pivoted mounts of the early nineteenth century, the crude wheeled and fixed disappearing carriages, some depending upon the use of weights and others upon springs, to the present state of perfection in "disappearing," "barbette" and "railway" carriages. Disappearing carriages apparently have reached the limit of their usefulness, and it seems probable now that no more will be constructed for our service. The idea of protecting such a gun from the view of the enemy by means of a parapet seems to have lost its value, partially through the great increase in the range of guns and partially through the introduction of airplanes. Such guns can, if desired, be mounted several miles back of the coast, because generally they must depend upon either airplane observation or observation from shore-line observation stations for their operation. The barbette carriage shown for the 16-inch 50-caliber gun is probably typical of the type of carriage that will be of maximum service for any type of gun in coast fortifications. This carriage provides for an elevation of 65 degrees, which is quite ample for mortars as well as guns. It is therefore the present limit in development.

ELEVATING MECHANISMS.

158. *Wedge.*—The mounting for the heavy wrought-iron guns of the fourteenth century is shown in Plate 69. It has already been explained that in using such guns they were brought to an advantageous point before a fortification and were trussed up to the

desired elevation by means of timbers, stone, dirt, etc., and left in that position until the wall had been breeched. Some of the early field guns of heavy caliber, two of which are mentioned as having been used in 1376 in the siege of Quero by the Venetians, were mounted in a wood cradle which was capable of slight rotation in a vertical plane on the carriage. This general scheme of elevation and the elevating mechanism is shown in Plate 60. As soon as guns were provided with trunnions in the next century it was the custom to use wedges, Plate 47, under the muzzle or breech, to give the gun the proper elevation. Elevations of 10 degrees were about the maximum for guns carried on trunnions, and the wedges easily sufficed. In the eighteenth century we find the use of a screw under the breech end of the gun becoming rather common for field cannon especially, and this mechanism has continued in use with considerable refinement even to the present day. Wedges were used in con-

PLATE 69.



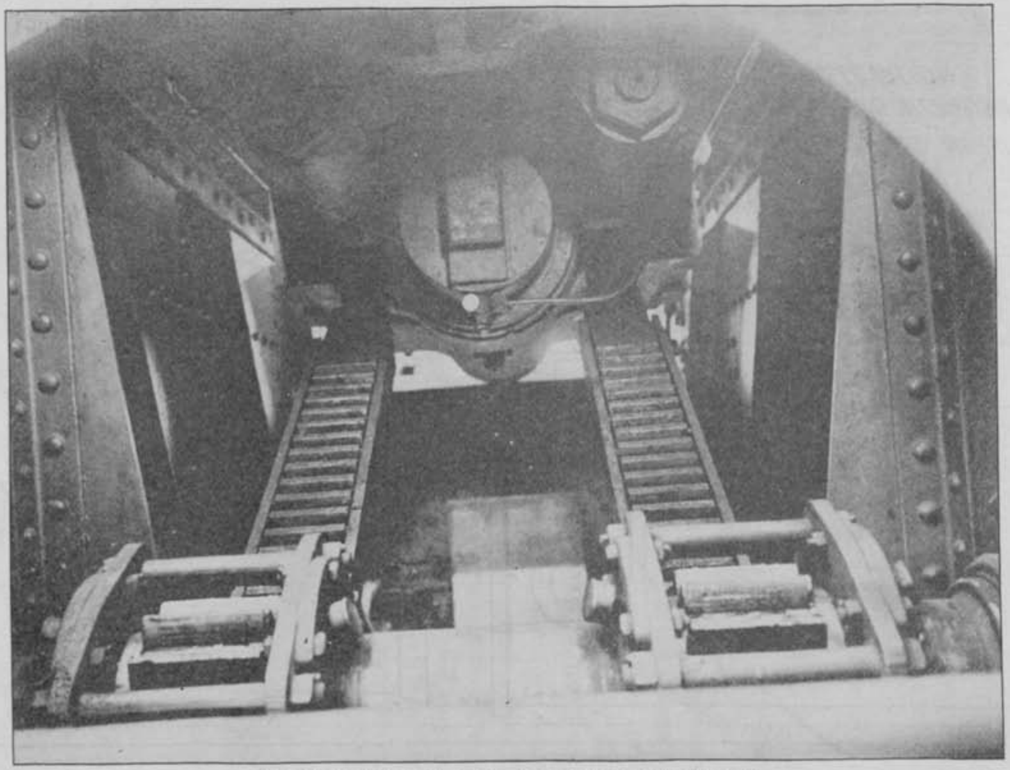
WROUGHT-IRON GUN ON CRUDE PLANK CARRIAGE.

nection with the elevation of guns probably as late as our own Civil War, and by other countries even later. There has been little possibility of developing the wedge in practical form for extreme ranges in elevation, and this device has therefore passed from use.

159. *Screw.*—The screw has lent itself with considerable ease to the extremes of elevation, and one finds it used rather generally on the carriages of both large and small guns on board ship, in fortifications, and in railway carriages. Numerous cases of the use of the screw are seen in Plates 62–66.

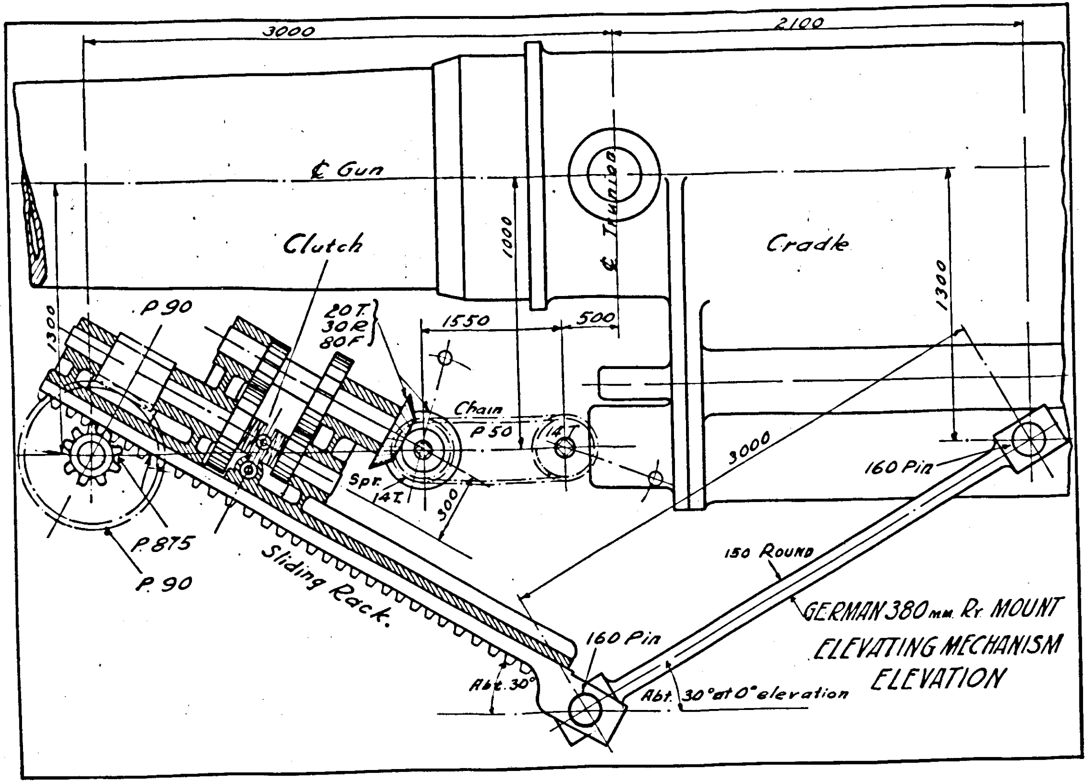
160. *Gears.*—It is not known definitely just when gears were first introduced for the purpose of elevating guns, but the carriage shown in Figure 1, Plate 63, shows the use of a rather unique double elevating rack. This scheme of elevation involved the attaching to the gun of either a circular or straight rack which meshes with a pinion which is the end of a train of gears leading to the elevating handle. One finds numerous modifications of this type of mechanism, some of which involve the attaching of a single circular rack to the bottom of the gun, some a double circular rack to the bottom of the gun,

PLATE 70.



GERMAN STRAIGHT RACK ELEVATING MECHANISM.

PLATE 71.


3000
2100
℄ Gun
℄ Trunnion
Clutch
Cradle
1000
1300
1550
500
P.90
20T.
30R
80F
Chain
P50
14T.
Spr.
14T.
300
3000
160 Pin
150 Round
P.875
P.90
Sliding Rack.
160 Pin
Abt. 30°
Abt. 30° at 0° elevation
GERMAN 380mm. Ry. MOUNT
ELEVATING MECHANISM
ELEVATION

others a single circular rack on one side of the gun, or on each side of the gun. The straight rack designs involve the pivoting of a straight rack to the bottom of the breech of the gun, Plate 70, or the connecting of the bottom of the breech of the gun by means of two connecting rods to a rack moving in a fixed plane in the bottom of the carriage, Plate 71. In the 16-inch barbette carriage which has just been finished, the circular rack has been used to considerable advantage in a combination that results practically in automatic elevation and depression. When a release lever in the elevating mechanism is pressed, the gun, if loaded, rises slowly to its firing position because of its breech preponderance. If the lever is pressed when the gun is elevated and empty, it slowly descends to its loading position because of a muzzle preponderance.

161. *Worm gears.*—In many elevating mechanisms involving the use of gears it was the practice during past years to incorporate a worm and worm wheel, Plates 63–66. These were introduced largely for the purpose of providing an automatic lock in the mechanism. It has been found that the introducing of the worm in the mechanism involves so much friction and consequent loss of power that during the last few years all mechanisms comprise spur gears only and a band-brake mechanism similar to that used on automobiles is introduced to serve as a partial lock as well as slip friction safety devices.

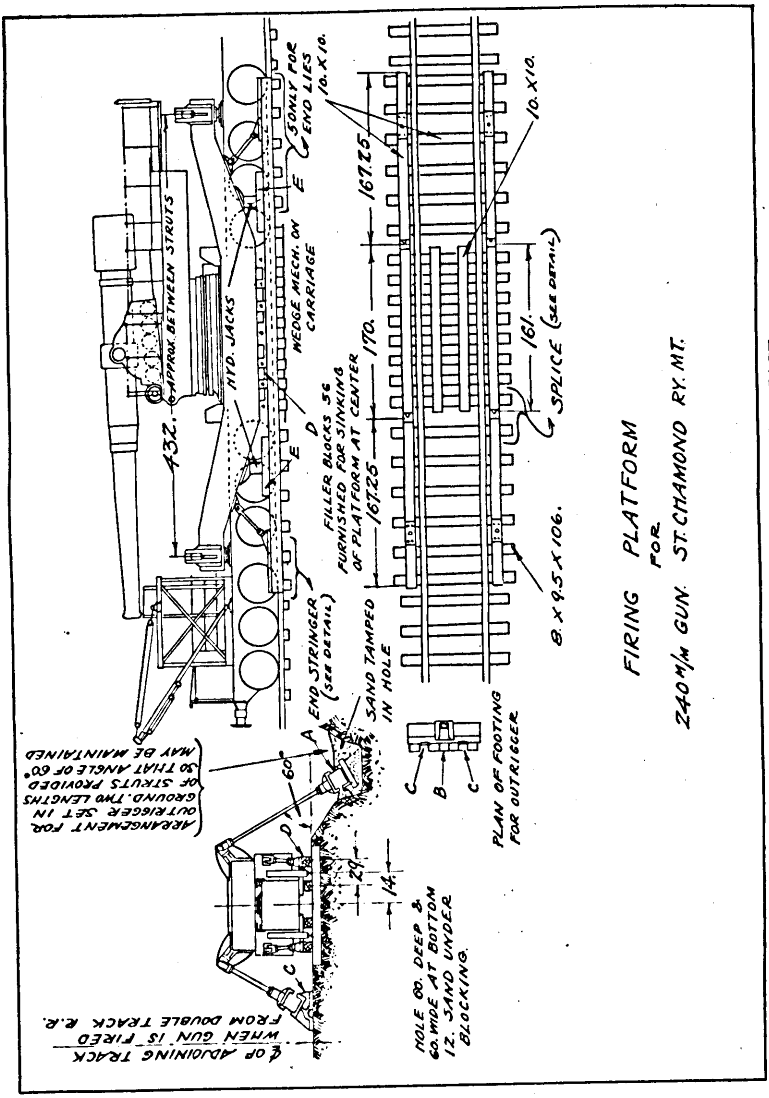
162. Elevating mechanisms may then be summarized as having been developed from the original crude scheme of mounting the gun with its wood platform on a mound of earth at the proper elevation, through the single and multiple wedge to the simple and compound screws and the combinations of gears and racks as we find them to-day.

RECOIL AND RECUPERATOR MECHANISMS.

163. The original scheme for preventing a gun from sliding to the rear on firing is shown in Plate 69. The gun merely rested on the wood platform or cradle that was provided and the recoil mechanism then comprised merely heavy timber stops that were driven into the ground. The next developmenet in recoil mechanisms comprised the mounting of the guns on two-wheeled field carriages and two or four wheeled truck carriages, Plates 47 and 60. In the case of the former, when the gun was fired the carriage rolled and slid to the rear and was stopped by the friction of the trail against the ground and the effort required to roll the wheels up a constant slight incline caused by the heavy wheels and carriage making a depression in the ground. In the case of the truck carriage, it was quite common to pass ropes from hooks on the side of the carriage over pegs in the ground or through eyes attached to walls in the front and then either around the rear of the carriage or to some post about which it might be tied.

In such cases the rope, being slightly elastic, would transmit rather easily the shock of recoil into the wall or peg about which the rope was passed. On shipboard it was quite common to put coils of rope, grass mats, loose bundles of canvas, bundles of hemp, etc., on the

PLATE 72.



FRENCH ROLLING-RECOIL TOP CARRIAGE.

deck behind the carriage. As the carriage rolled over these obstructions it was gradually brought to a rest. It was the practice later on shipboard to use the training ropes for the purpose of checking recoil.

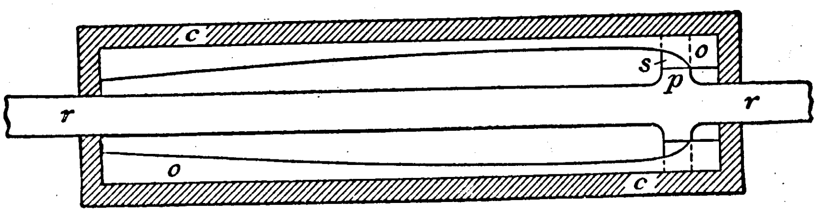
164. *Inclined plane.*—It seems probable that the scheme of compelling the carriage to roll up an inclined plane must have been used at a very early time, because the recognition of the possibilities of this scheme would not involve any technical skill or knowledge. It would seem, therefore, that this scheme of checking recoil must have been used almost simultaneously with the mounting of guns on wheeled carriages in the fourteenth century. The scheme of checking recoil by requiring a carriage to roll up an inclined plane has been tremendously elaborated upon and is in common use even now. Plate 72 shows an example of present-day uses of this scheme. Most of the designs of this type that we find now in use remain over from a period of 30 to 50 years ago when it was considered a good design. As the power of guns has increased it has been necessary to add so many other mechanisms to the inclined plane that we have come to the conclusion that the work done by the top carriage in climbing the inclined plane is so small a percentage of the total work required to be done that it is not profitable to use it.

165. *Counterweight.*—The next step in the development of recoil mechanisms involves the harnessing of a weight moving vertically to the carriage in such a way that when the gun recoils it is compelled to raise the weight. The combination of this together with a more recent development in mechanisms is still in use in our disappearing carriages; the weight in this case weighs as much as 600,000 pounds. In all of the mechanisms mentioned so far no cases have arisen where any effort has been required to return the gun to its firing position. In each case the force of gravity returned the gun to its normal position either through the pull of the weight or through the running of the carriage down the inclined plane.

166. *Hydraulic brake.*—Early in the nineteenth century the hydraulic mechanism, which has been developed to such a high degree at the present time, was introduced in the form shown in Plate 70. This was exceedingly crude, but modifications of this form persist even to the present day, as has been mentioned before. The merit of this particular form of the mechanism is that it serves both to check the recoil and to return the gun to its original position, which was particularly to be desired on the disappearing carriage on which it was first used. This mechanism might be considered a hydropneumatic mechanism and may be considered a forerunner of one of the present rather sharply divided mechanisms which come under the head of hydropneumatic recoil mechanisms. But little further was done in the development of mechanisms involving only weights or the use only of inclined planes. The plates that have already been mentioned serve to illustrate these in their final form.

167. *Graduated orifices.*—Since the power of guns continued to increase very rapidly from the middle of the nineteenth century it was necessary to modify the hydropneumatic recoil mechanism just mentioned. The first modification that we find is in the use of a cylinder filled with oil which was compelled to pass through an orifice in the piston when the gun was fired. This mechanism is almost identical with the common stop that we find on the doors of buildings to-day. In connection with this type of mechanism, springs or weights were used to return the gun to its normal position. Such combinations are in use to-day. The hydraulic cylinder has been tremendously refined and we find in Plate 73 that the orifice through which the oil is required to pass, instead of being simply a round hole in the piston, is now so graduated as to correspond at all times to the force being exerted by the gun. For this purpose we find in some cases that grooves of a uniform width but varying depth are cut in the walls of the cylinder, in other cases slots of

PLATE 73.



RECOIL CYLINDER WITH VARIABLE ORIFICE.

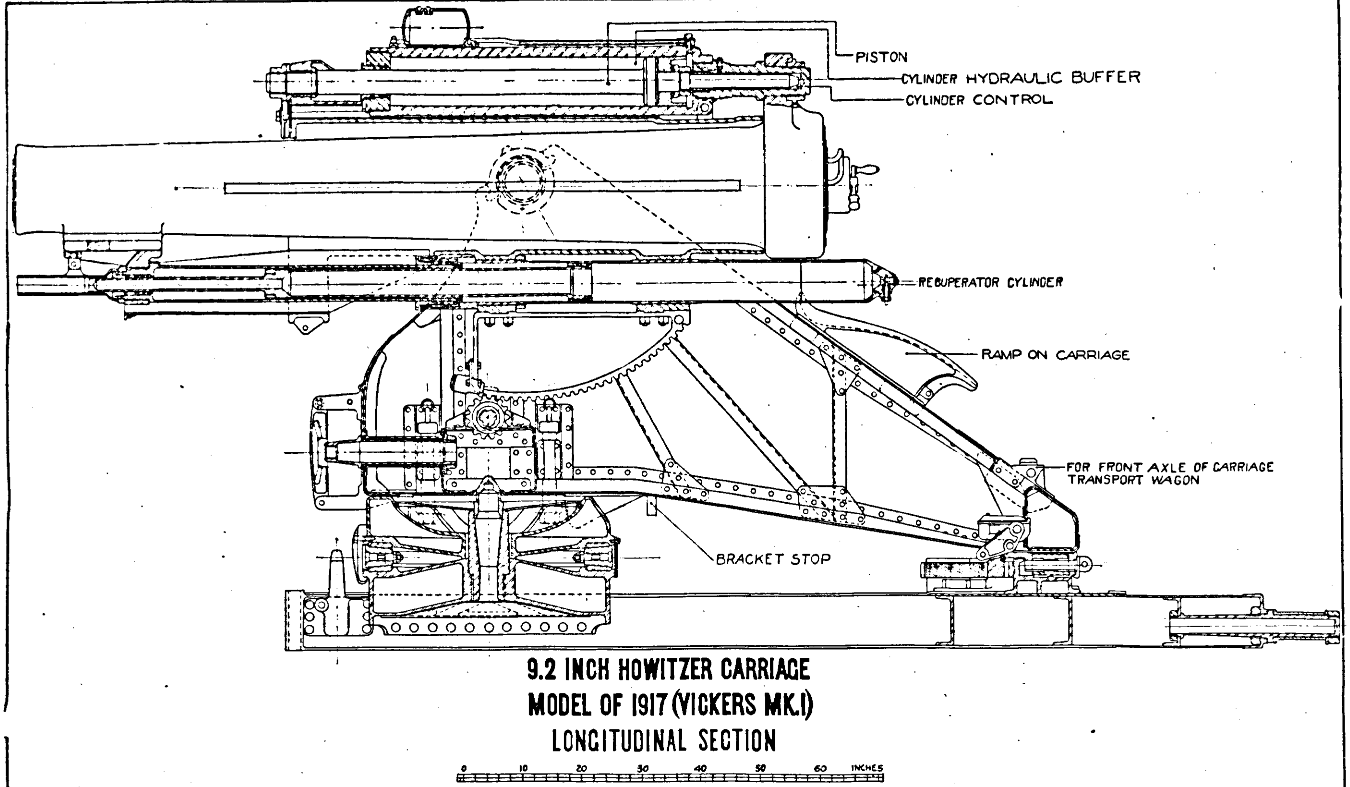
uniform widths and depths are cut in the piston, and bars of uniform widths but varying depths are attached to the walls of the cylinder. The third variation involves holes of uniform diameter in the piston and round rods of varying cross section passing through these holes and attached to the ends of the cylinder. The piston rod is always attached to a lug or band on the gun, and as the gun recoils the piston is compelled to move with it and the oil is compelled to pass through the orifices. Since we are in the habit of combining with this some mechanism which pulls the gun back into its firing position, it has been necessary to provide some form of what is known as a counter-recoil buffer which will prevent the gun from coming back into battery with too great a shock. There are various forms of such buffers, two of which are illustrated in Plates 123 and 235. In the one case the recoil piston rod is merely continued into a head which fills with oil as the gun recoils. When the gun is brought back into battery the oil is forced out of this pocket rather slowly and prevents the gun from returning too violently. The most refined form of buffer is that shown in Plate 123, which has been developed for the 16-inch gun on its barbette carriage. This

involves a floating valve which opens quite freely when the gun recoils but closes when the gun is being returned to battery and prevents the oil from passing from one end of the cylinder to the other except quite slowly. The first type mentioned was not found satisfactory for heavy guns which must operate between the ranges of zero and 65° or even 45°. This new mechanism has been found entirely satisfactory for the operation of even so heavy a gun as the 50-caliber at the extremes of elevation of zero and 65°.

168. *Spring recuperators.*—The earliest type of recuperators that followed the use of weights comprised helical springs, Plate 217, upper view. Such recuperator mechanisms were in use in our service from at least 1870 and are still in use on some of our guns. The German service very distinctly prefers spring recuperators, and practically all of their field carriages as well as their heavier coast and naval carriages use this type. The British service seems to prefer this type likewise for their heavier guns. We have had sufficient experience with the pneumatic recuperator during the past war to induce us to practically abandon springs for future field and coast carriages.

169. *Pneumatic recuperator.*—Between 1880 and 1890 Colonel Duport, of the French Army, developed the famous French 75-millimeter gun involving a hydropneumatic recoil mechanism in which a pneumatic recuperator involving a metal piston between the air and the liquid replaced the usual springs. It is possible that this type of mechanism may have been proposed by some one else, but this seems to be one of the earliest cases of its being successfully used on a field carriage. This combination had the advantage of permitting a very long easy recoil and the result was an unusually steady carriage. This distinctly pneumatic recuperator has been developed for a field carriage carrying a 6-inch gun and for heavier coast and railway carriages carrying guns as large as 21 inches. In Plate 125, the design used on several of our railway carriages as well as on the 16-inch 50-caliber barbette carriage is shown in detail. It will be observed here that the mechanism involved a floating piston and that a liquid seal is provided against the escape of the air in the air chamber. Thus, if there is any leaking from the recuperator it is oil that is lost, and as this oil leaks out the rod of the floating piston projects slowly from the end of the main piston, indicating clearly the extent of the loss of oil. This type of recuperator has been found from quite sufficient trial to be so satisfactory and efficient that it has been rather generally adopted for use in our seacoast carriages. The form of pneumatic recuperator which is being used by the British service on its field carriages is simply a development of the original type of the hydropneumatic recoil mechanism shown in Plate 74. This refined mechanism in-

PLATE 74.



9.2 INCH HOWITZER CARRIAGE
MODEL OF 1917 (VICKERS MK.I)
LONGITUDINAL SECTION

CLASS 36 DIVISION 3 DRAWING 148

BRITISH FORM OF PNEUMATIC RECUPERATOR.

volves a double cylinder, the one of which is principally an air reservoir. As the gun recoils the oil in the recuperator cylinder is forced into the air cylinder, thereby compressing the air still further. When the end of the recoil has been reached, the air forces the liquid out into the recuperator cylinder and returns the gun to battery.

170. Recoil and recuperator mechanisms may then be summarized as having developed from the original back stop of timbers, Plate 69, through the wheeled carriage stopped by friction, the truck carriage stopped by obstacles and by means of ropes, the inclined plane, the weight, the early combined hydropneumatic mechanism, Plate 66, to the combination of weights and hydraulic mechanism on the disappearing carriage, Plate 176, the hydraulic cylinder and springs, Plate 217, and the hydraulic cylinder and pneumatic recuperator of the two types shown in Plates 74 and 125. It is possible that one should add to this the sliding friction scheme of the sliding railway mount and the rolling friction scheme of the rolling railway mount, Plate 68.

BREECH MECHANISMS.

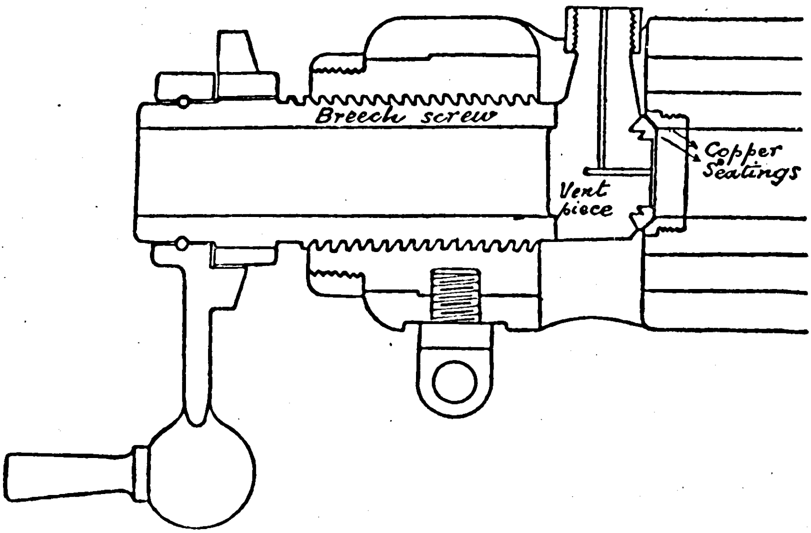
171. *Wedge.*—From the time that guns were first made in 1250, it is probable that the advantages of being able to load a gun from the rear were seen. Crude open-tube or breech-loading guns were made early in the fourteenth century; that is, about 1325. Practically all of these early breech mechanisms involved the use of a wedge. Among the first mechanisms we find the breech-loading scheme of the so-called "wall" gun, in which the breech served as the powder chamber and was held in place by means of a metal wedge, Plate 43. These mechanisms were so crude, however, that they did not find great favor. In the heavier guns, which were of cast metal, the use of such a mechanism generally weakened the breech to such an extent as to result frequently in the failure of the gun. From 1325 until the early part of the nineteenth century breech-loading guns were constantly in existence and in occasional use. Practically all of the breech mechanisms of those centuries, however, involved the use of a wedge in some form.

172. In 1845 Major Cavalli, a Sardinian officer, devised the wedge scheme shown in Plate 54, and in the next year the Wahrendorff breech was devised, involving again the use of a wedge together with a simple locking screw. It was so difficult to obtain absolute obturation with these wedge mechanisms, however, that they did not meet with a great deal of favor.

173. *Screw.*—In 1854 Sir William Armstrong in his experiments on breech-loading guns developed a screw breech mechanism, Plate

75, which though somewhat elaborate gave more satisfactory results than any of the wedge mechanisms so far used. From this time on the breech-loading gun was firmly intrenched, and the various breech mechanisms operated with a relative degree of satisfaction. In England, France, and America the screw breech has been developed from the types shown in Plate 43 to the modern type of mechanism, Plate 121, which is being used on our 16-inch gun, where we find the breechblock hinged at the bottom of the gun closed automatically by means of air pressure in the closing cylinders under the gun, and locked by a one-sixteenth revolution of the block. In coming to this type of screw, which is known as the Welin stepped-thread screw, we have passed through the simple in-

PLATE 75.



ARMSTRONG (BRITISH) BREECH.

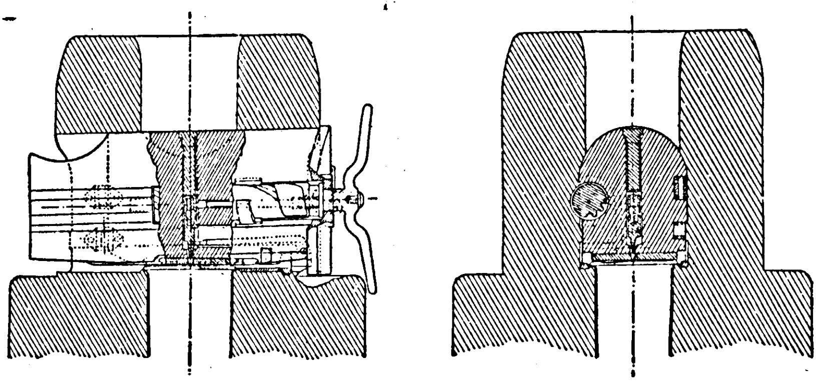
terrupted screw with three or four alternate sections of thread on the block, Plate 209, to the present scheme of machining the block to 4 diameters and dividing the circumference into 16 parts, 12 of which are threaded and 4 are recessed. By this last scheme we secure contact between a much greater percentage of the block and the gun than formerly and the block is released and locked by a very slight rotation.

174. *Obturator pads.*—The screw breech mechanisms involved the use of some form of gasket or gas-check pad which bears heavily against a cone machined in the breech of the gun. This scheme of preventing the escape of gases is only relatively satisfactory. Under hard service in the field these pads insist on swelling when new and on permitting the escape of gases and the scoring of the cone when

old. The pads are made of asbestos soaked in tallow, covered with wire cloth, and compressed under terrific pressure. The steel mushroom head in front of the pad protects it against the heat of the powder gases to a certain degree.

175. *Krupp breech.*—The wedge mechanism that we saw in the Cavalli and Wahrendorff guns has been developed by the German Army in the Krupp Ordnance Works to the perfection shown in Plate 76. Apparently they have used it on all of their ordnance, even the famous 42-centimeter guns which were used in the destruction of the forts of Liege in 1914. The use of this type of mechanism compels the use likewise of metal powder cases, because there is no other practical means of preventing the escape of gases to the rear. The introduction of the expandable metal powder cases in France in 1846 opened the way for the development of the wedge breech mechanism as we find it now in Germany. In the 3-inch caliber

PLATE 76.

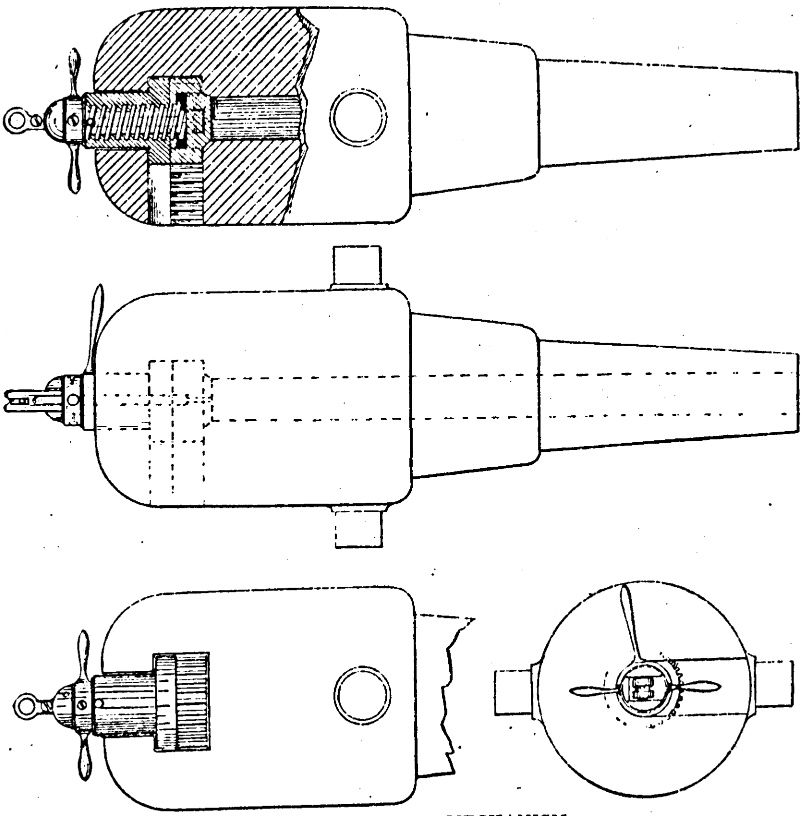


KRUPP SLIDING-WEDGE BREECH MECHANISM.

guns the ammunition is "fixed"; that is, the projectile is fastened into the metal powder case. Above this caliber the ammunition is generally separate. In some instances the entire powder charge is contained in a metal case, while in others only the base charge is contained in a metal case because it would require a case of too great weight and size to contain the whole charge. The principal purpose of the case is to prevent the escape of the gases to the rear. After the projectile is rammed, the powder charge is entered either separate or in the case and the case slid into the breech until its rim strikes the breech end of the gun. The powder case varies in thickness from the base to the forward end, and the forward end is forced against a cone machined in the powder chamber of the gun. The closing of the screw breech forces the front edge of the case very hard against the cone and the rim of the case against the breech of the gun. In this system the primer is always provided in the base

of the powder case. When the explosion takes place, the pressure of the powder forces the thin edge of the powder case tight against the cone and prevents the escape of the gases to the rear. This type of mechanism has a few advantages. First, no difficulty is experienced with swelling of obturator pads. Second, there are no serious difficulties with firing mechanisms such as one experiences in the case of the screw breech. Third, it seems a simpler type of mechanism to manufacture and maintain. We have made use of this

PLATE 77.



THOMPSON BREECH MECHANISM.

mechanism on our antiaircraft and newly designed 3-inch field guns. In some cases the wedge is made to slide crosswise and in others up and down.

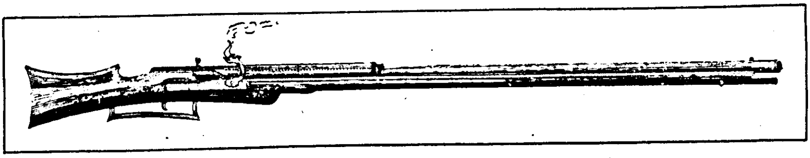
176. In summarizing breech mechanisms, we find that although the development has continued from 1325 to the present day, we have been working on only two types, the one involving the wedge and the other the screw, which, after all, is a wedge also. The earliest mechanism employed a separate powder chamber and the

intermediate mechanisms are illustrated by the Cavalli and Wahrendorff types. One other distinct type, Plate 77, has been proposed which is neither a wedge nor a screw. This type, unfortunately, does not possess any very satisfactory means of closing it tightly and would not serve for guns of modern design.

FIRING MECHANISMS.

177. *Match, wheel, and flint.*—The earliest scheme employed for discharging a gun was to apply a cotton or hemp match to the bit of

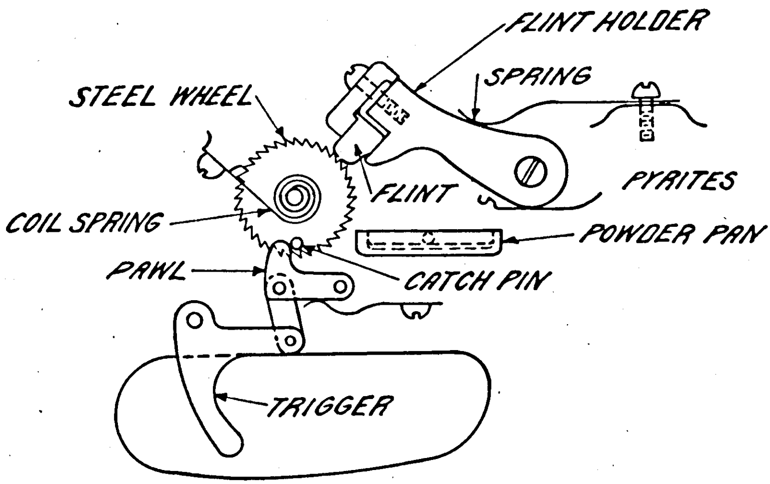
PLATE 78.



EARLY MUSKET WITH MATCH LOCK.

powder about the vent or in the pan over the vent of the muzzle-loading gun. This scheme was in common use until after our own Civil War. In the sixteenth century hand rifles were developed having a more or less automatic scheme of firing, where the match of cotton or hemp was carried by a hammer which dropped to the firing

PLATE 79.



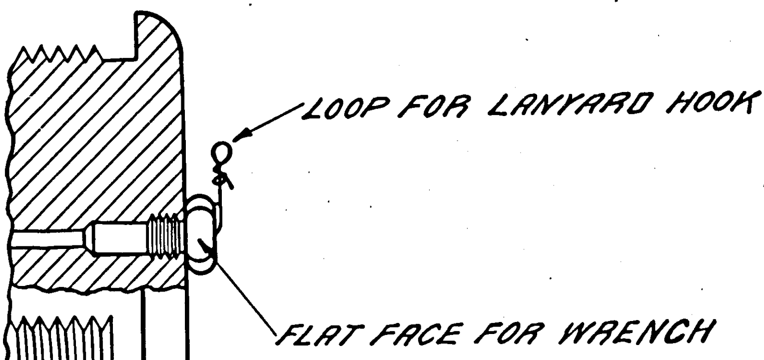
SMALL FIRING MECHANISM WITH WHEEL LOCK.

pan on its release by the trigger, Plate 78. In this same century the wheel lock, Plate 79, was devised, where we find a small hard-steel wheel with roughened filelike circumference being rotated rapidly against a small piece of iron pyrites. This lock included a coil spring which was wound, and on the release of the trigger the spring would

spin the wheel, which would cause a shower of sparks to fall into the powder pan and fire the gun. This mechanism was superseded by the flintlock, where the hammer of the gun carried a chip of flint which on the fall of the hammer struck a small plate of steel, causing several sparks to drop into the powder pan and fire the gun. It is understood that both the wheel lock and the flintlock were employed on some large guns. One British man-of-war had several of its guns provided with flintlocks.

178. *Detonator lock.*—In 1805 a Reverend Forsyth devised a detonator lock which comprised a magazine shaped like a bottle and attached to the lock of the gun. This bottle contained a detonating mixture of potassium chloride, charcoal, and sulphur. A rotation of the magazine caused a small quantity of this mixture to fall into a

PLATE 80.



RUSSIAN PRIMER THAT IS SCREWED INTO HOLDER.

small hole in a plug communicating with the touchhole of the gun. A second rotation of the magazine brought this detonator charge into such a position that it could be set off by the fall of a hammer. Forsyth developed this mechanism to the point where it was more or less satisfactory for sporting rifles, and serious attempts were made to develop it for cannon. His experiments were followed so closely, however, by the invention of the fulminate cap by Mr. J. Shaw, of Philadelphia, in 1814 that it was not developed to any great extent.

179. *Fulminate cap and primers.*—In 1814 the fulminate cap, first of iron, then of pewter, and finally of copper, was developed and came into general use for small arms. Relatively small use was made of the fulminate which was employed in these caps until about 1850, when a friction primer was developed in England that could be

introduced into the vent of either a breech or muzzle loading gun. This primer was in itself a firing mechanism in that it was complete. The operation of this mechanism probably needs no explanation, since it is so similar to the primers we are using to-day. This type of primer is in use even to-day. Plate 80 shows another form of this primer in the shape of a threaded cylinder which is screwed into the breech of the gun. It is a friction primer and was in rather general use by the Russian Army on their 105-millimeter guns. A large number of these primers were found with the 105-millimeter nonrecoil guns which were captured by the Germans and then recaptured by the Americans from the Germans at Margut, Belgium, in 1918.

180. Firing mechanisms of to-day comprise simply various designs of holders for cartridgelike primers fired by friction or electricity and other holders for other cartridge-shaped primers fired by the blow of a hammer. The designs are legion, while the principle of serving as a holder with or without a hammer is common. Difficulties experienced with some mechanisms have been discussed under fuses and primers.

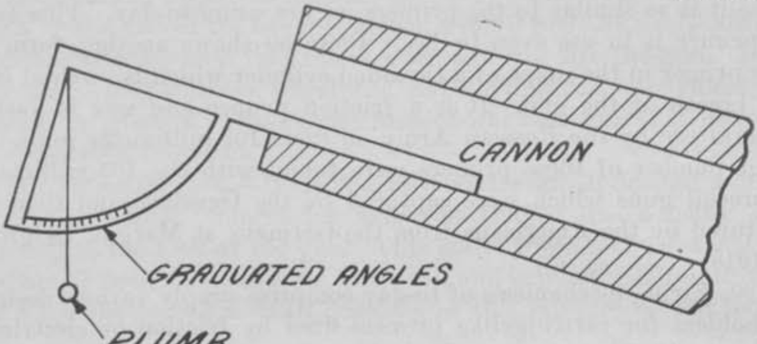
181. Firing mechanisms have then been developed from the match, through the wheel, flint, and detonator locks, and the fulminate cap with hammer lock to the primer holder of to-day, in which the primer is fired by friction, electricity, or the blow of a spring-driven hammer.

SIGHTS.

182. *Quadrant.*—For several centuries there was little or no need for sights of any description in connection with the laying of guns. During the period from 1250 to 1550, when the projectiles were stones, the target was generally a wall or a ship, and the gun had a range of only a few hundred yards. When firing at a wall the gun could easily be pointed in the direction of the point to be breached without the aid of sights. It was early learned, however, that with a certain weight of powder and size of projectile the gun should be elevated to an approximate number of degrees to hurl the rock projectile to the desired distance. To facilitate this laying or placing in elevation a crude form of our present gunner's quadrant was devised by Tartaglia in 1540–1550. The original and present quadrants are shown in Plates 81 and 82. This original quadrant comprised two legs at 90°, the one leg being longer than the other in order that it might be inserted into the bore of the gun. The arc connecting the two legs was divided into 12 parts, and projected past the one leg some degrees to provide for laying the smaller guns in depression. A plumb line was suspended from the vertex of the angle. This instrument served for the high as well as low angles of elevation and depression.

183. *Dispart and tangent sights.*—Early in the seventeenth century the practice was introduced of providing guns with what were

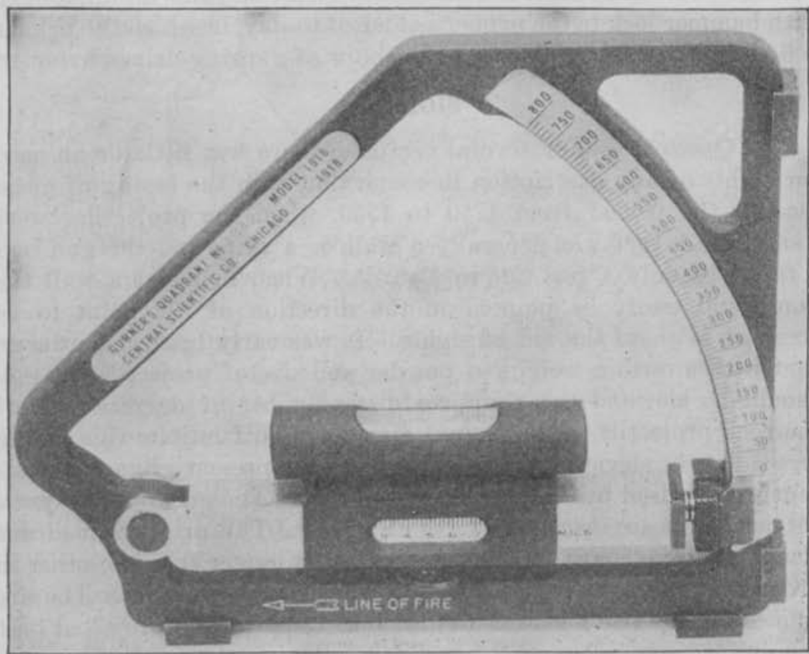
PLATE 81.



TARTAGLIA'S GUNNERS QUADRANT.

known as "dispart" sights. A notch was made on the top of the breech or base ring, and on the muzzle ring a notched fore sight (termed the dispart sight) was placed in the same vertical plane as

PLATE 82.

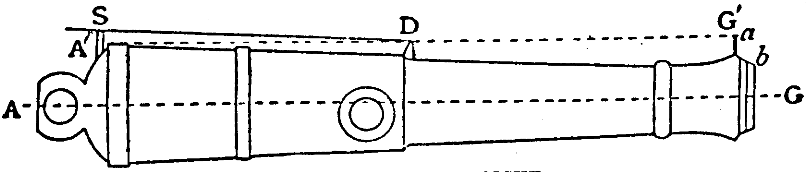


GUNNERS' QUADRANT OF TO-DAY.

the breech notch and the axis of the gun, and at such a height that a line from the breech-ring notch to the dispart-sight notch was

parallel to the axis of the gun. Such sights served well for short-range firing, but assisted only in laying the gun in direction. For more distant firing the quadrant was still necessary. The next development took the form of a gunner's rule or tangent sight ar-

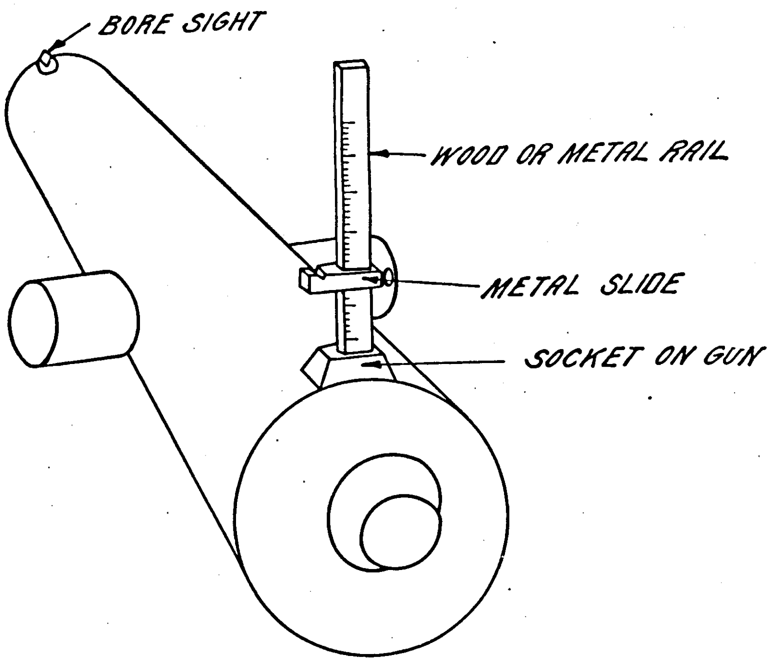
PLATE 83.



ORIGINAL TANGENT SIGHT.

ranged as shown in Plate 83. In this case a brass rule was used having a slit in the center and graduated into divisions proportional to the tangents of angles, with a base equal to the distance from the rule to the dispart notch. A metal rider was provided across

PLATE 84.

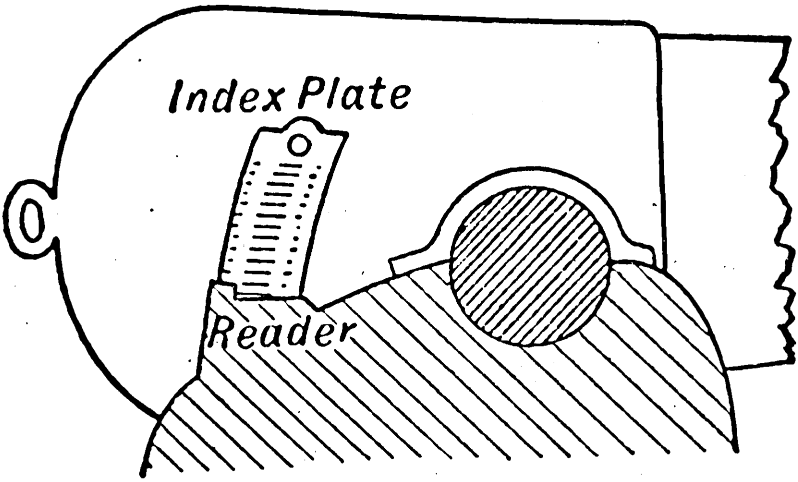


EARLY AMERICAN TANGENT SIGHT.

which a thread with a bead in the center could be stretched. When the thread of this rider was set at any desired elevation according to the graduations on the rule, the gunner could lay his gun both in elevation and azimuth by sighting from the bead over the dispart sight. Similar designs of tangent sights were introduced by General

Gribouval in about 1775, and were in general use in America by 1812. They were not generally adopted in the British Navy, however, until about 1850. The American tangent scale comprised a brass scale, Plate 84, that fitted into a socket in the breech ring

PLATE 85.

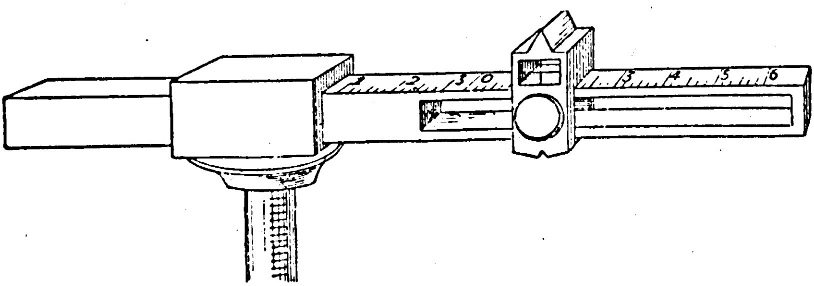


TANGENT SIGHT WITH GRADUATED PLATE FOR INDEXING ELEVATION.

of the gun, and it could easily be removed when desired. This brass scale provided for elevations up to 5 degrees. For elevations up to 10 degrees a wood scale was substituted.

184. Since sights of this design were so easily liable to injury both in firing and handling the gun, another form of the tangent

PLATE 86.



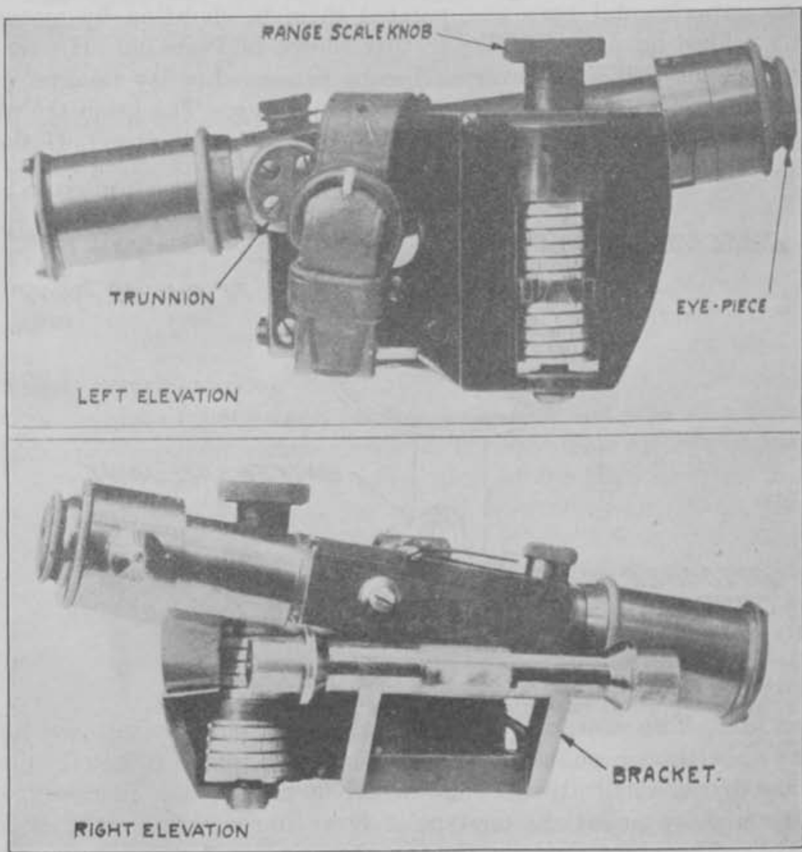
TANGENT SIGHT WITH ADJUSTABLE DRIFT SCALE.

sight was devised. This, Plate 85, comprised a series of notches on the side of the breech ring and a single notch on the side of the muzzle ring. These notches were high enough that a line from the lowest rear notch to the muzzle notch passed over the trunnion and was parallel to the axis of the gun. Such sights provided for an

elevation of about 3 degrees. Not infrequently the dispart sight was placed just over the trunnion.

185. *Drift scale—Telescopic sight.*—The further development of the scheme or design employed with American tangent sights was to provide separate dispart sights as well as scales, both of which fitted into holes or sockets in the body of the gun. The dispart or forward sight was generally placed about at the trunnions. Not

PLATE 87.



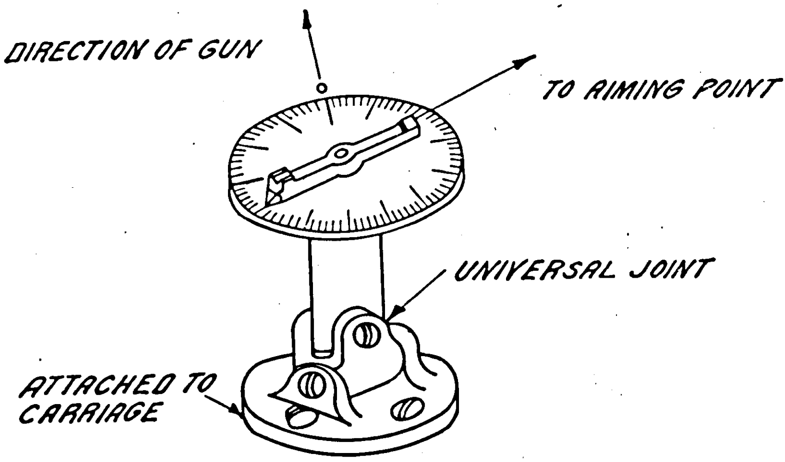
TELESCOPIC SIGHT.

infrequently sights were provided on both sides of the gun, and in the case of rifled guns the tangent bar or scale was inclined to the right or left of the vertical to compensate for the drift of the projectile. Since the drift angle varies with the muzzle velocity, the tangent scale of howitzers was set vertical and provided with an adjustable slide at its top, Plate 86, so that variations might be made in the offset for the various velocities. Mechanical sights were still further refined in construction, but in general followed the

principle of those just described as long as the scheme was continued of laying a gun both in direction and elevation with the same mechanism. Since 1880 the range of guns has been such as to require telescopic sights, Plate 87, to permit accurate following of the target.

186. *Panoramic sight.*—In 1855 Sir William Armstrong devised what may be termed a crude type of the now commonly known and used panoramic sight. He was conducting some night tests of some experimental guns and pointed them in elevation by means of a refined quadrant similar to that shown in Plate 88. His target was not visible, however, and so he proceeded to lay the gun in direction by what is known as indirect sighting. The geometry of this procedure is illustrated in Plate 89. T is the target, G the

PLATE 88.

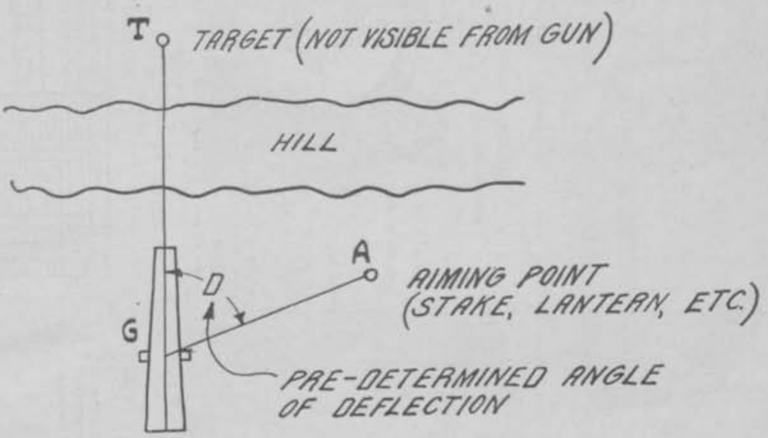


EARLY TYPE OF PANORAMIC SIGHT.

gun, and A an arbitrarily chosen or located aiming point. In the day this aiming point may be a point on a distant object, or a stake driven vertically at some convenient place. It is necessary to determine by means of some type of surveying instrument the angle TGA. The sight used on the gun for the purpose of laying in direction is provided with an element, containing the object lens, which is capable of rotation about a vertical axis to any desired extent and the angles are measured on a horizontal circle. When angle TGA is given, the rotating element of the sight is turned till the indicator is at the given angle. The gun to which the sight is attached either directly or indirectly is then rotated till the vertical line of the sight is on the object or point selected as the aiming point. A vertical plane through the axis of the gun then passes through the target. Sir William Armstrong employed a crude form

of this panoramic sight and used a lantern with a vertical slit in it for the aiming point in his experimental work in 1855. As the effective range of guns increased, the need for a sight that would

PLATE 89.



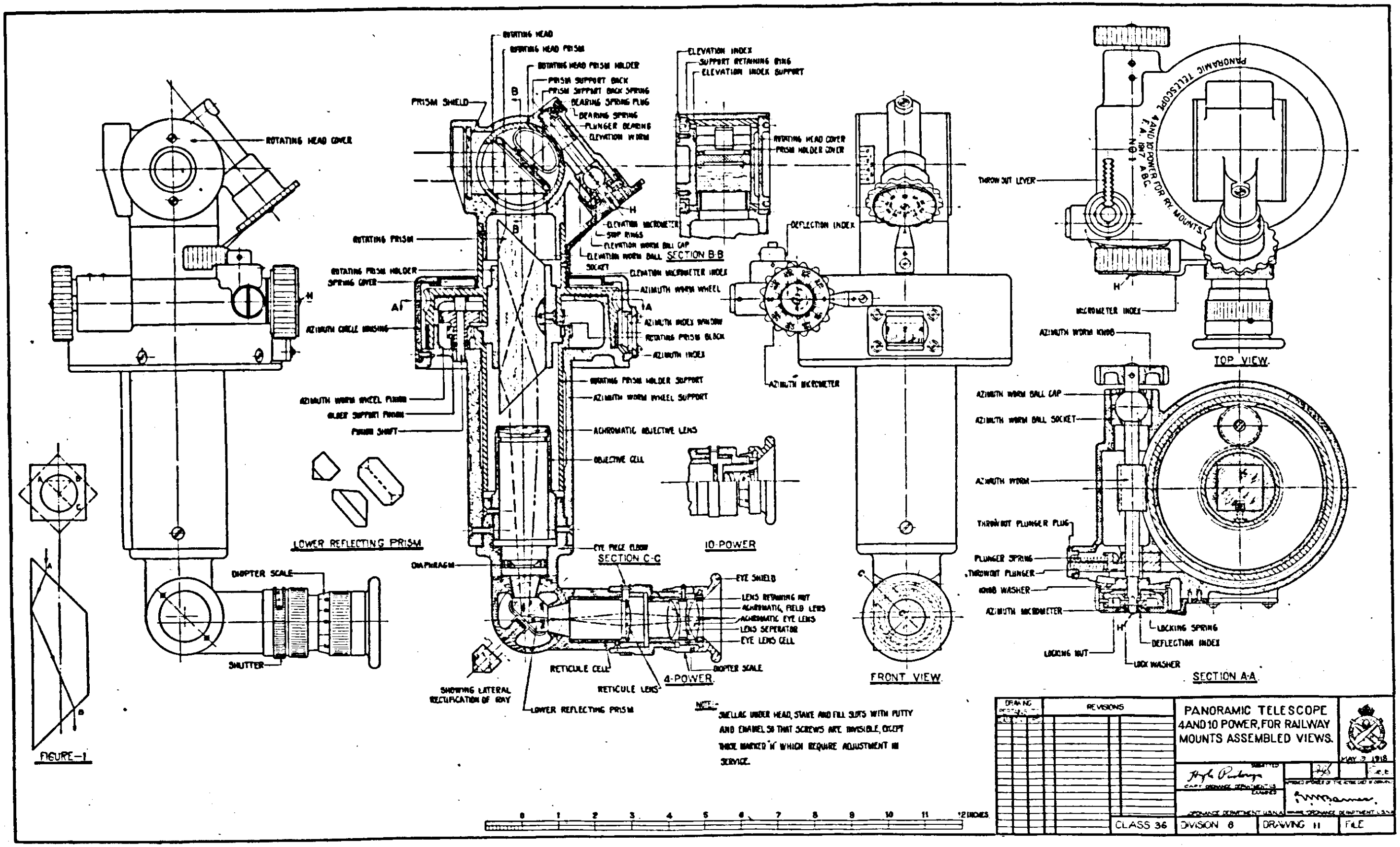
THE GEOMETRY OF INDIRECT FIRING.

permit accurate laying on distant targets resulted in the substitution first of a telescope for the open sight and later of a panoramic telescope for unseen indirect laying. The first panoramic sights were of the open design. Mirrors were then substituted and later the panoramic telescope approximately as we have it to-day. Plate 90. As long as sights were attached to guns or carriages in such a manner that the elevating or depressing of the gun acted to elevate or depress the line of sight, these sights were termed dependent. The sights of small arms to-day are of the dependent variety, and it is to be kept in mind that the target is visible. As the range and accuracy of guns improved to the point of making it possible to operate on invisible targets, the sighting of a gun became a double operation—that is, of laying both in elevation and direction. This necessitated the modification of the sighting attachment to the extent of making it independent of the motion of the gun in elevation. The sighting telescopes of modern carriages are therefore practically all so mounted as to have an inde-

PLATE 90.

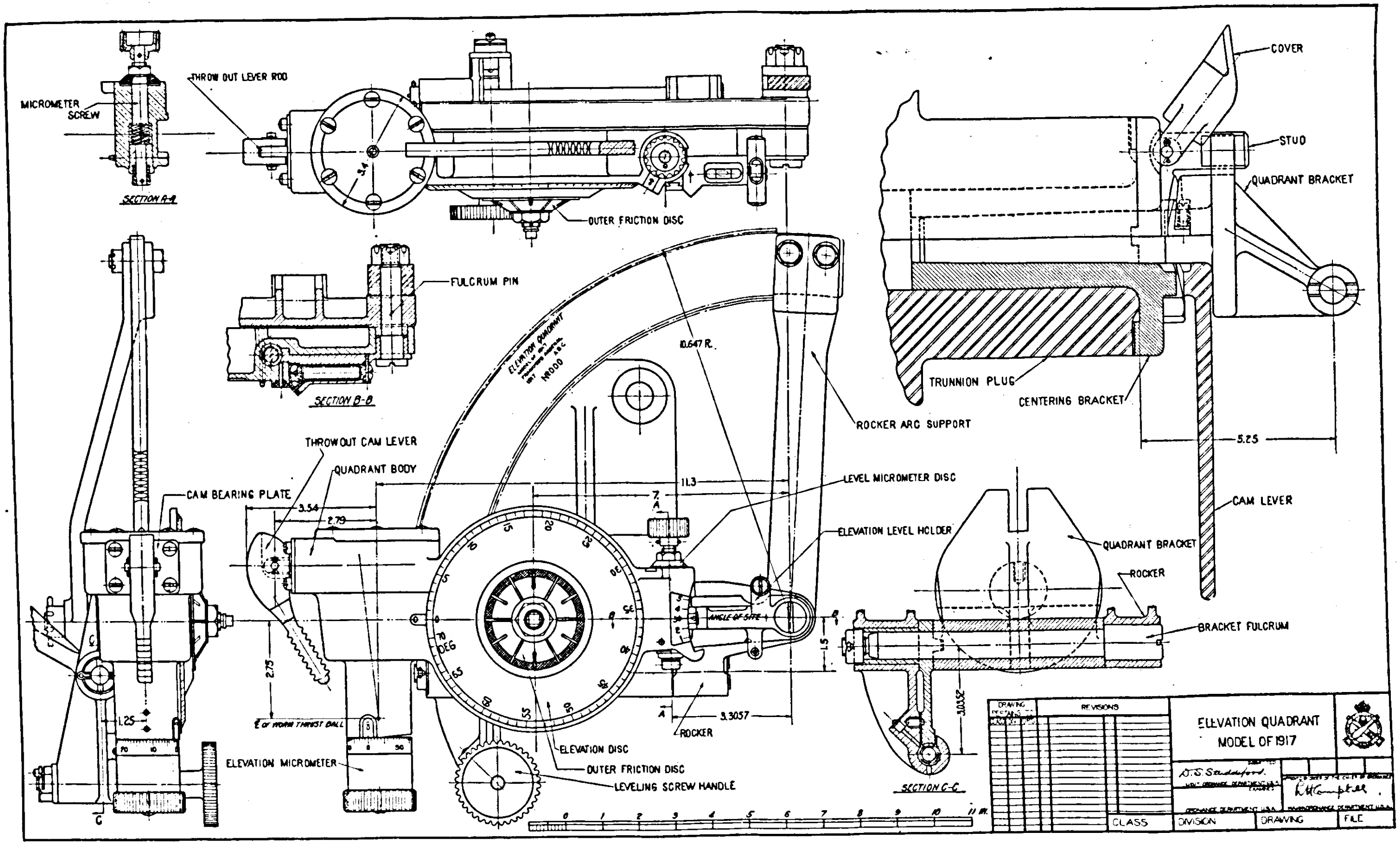
PRESENT PANORAMIC SIGHT.

PLATE 91.



PRESENT PANORAMIC SIGHT SHOWN IN DETAIL.

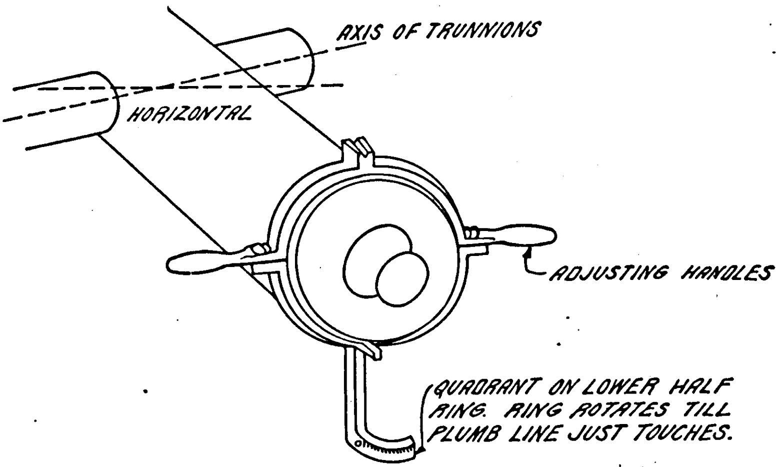
PLATE 92.



ELEVATION INDICATOR OF A MODERN SEACOAST CARRIAGE.

pendent line of sight, it being the function of this sight to enable the operator merely to lay the gun in direction, in which case, of course, the line of sight has nothing to do with the elevation of the gun. The operation of laying the gun for elevation is another and distinctly separate operation. We have therefore at the present time practically a dual sighting mechanism, part of which comprises a telescope capable of being adjusted so that its axis is vertical and provided with a graduated horizontal circle for laying off the desired horizontal angles. The gun is provided with some modification of the quadrant with a graduated vertical circle for the laying off of vertical angles of elevation. This quadrant may be either separate and used in connection with a machined pad on some part of the gun, or rigidly attached to some convenient part, like the trunnions.

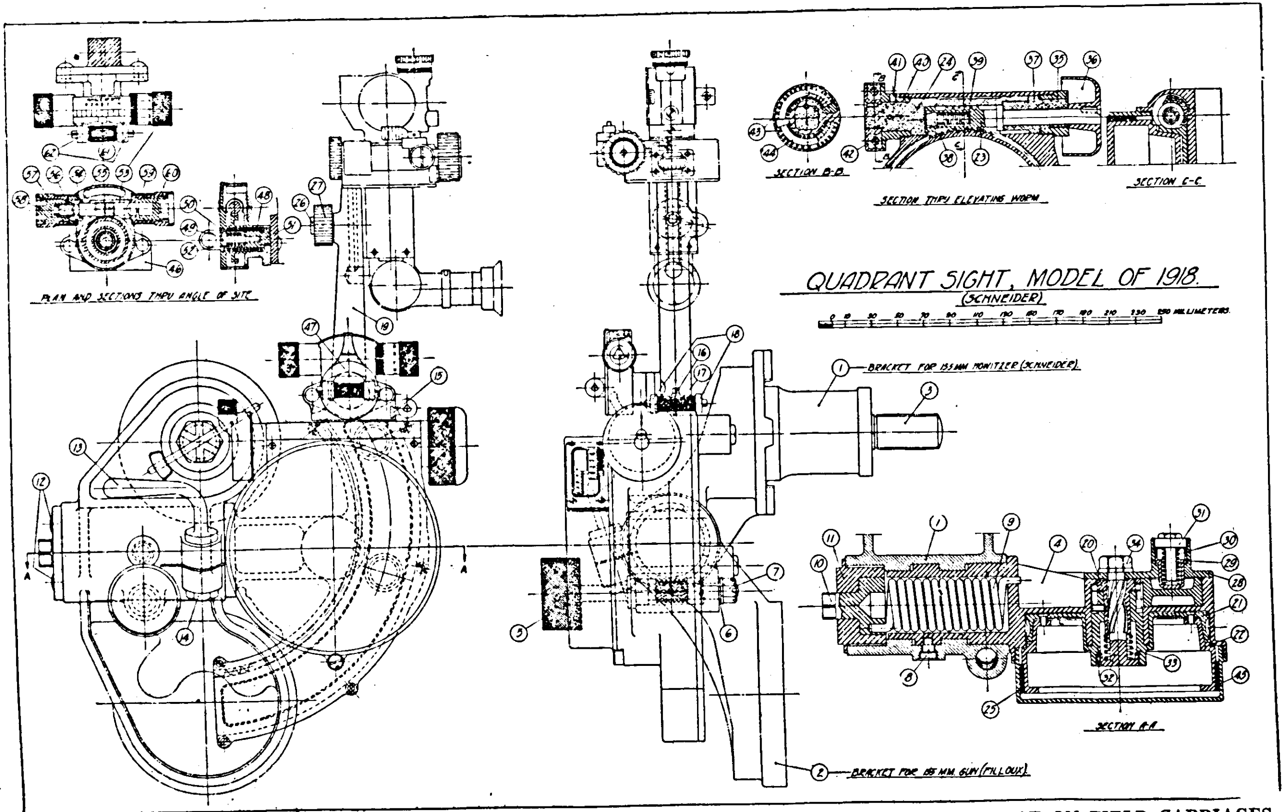
PLATE 93.



EARLY TRUNNION SLOPE COMPENSATOR.

187. The latest forms of the elevation and indicator sights for seacoast guns are those in use on the 16-inch barbette carriage, Plates 91 and 92. It will be observed that for laying in elevation a series of gears connect the gun with the dial registering the elevation angles. The base ring of the carriage is provided with an azimuth circle, graduated to degrees. An indicator attached to the racer, Plate 149, rotates with the gun and indicates an indirect deflection from a fixed aiming or reference point. The operator located in the azimuth observer's cab rotates the carriage until the indicator is at a point on the azimuth corresponding to the deflection angle determined and telephoned from the observing stations. For direct fire at a stationary target or for following a moving one azimuth is obtained with a telescopic sight having deflection adjustments for target speed, wind, etc.

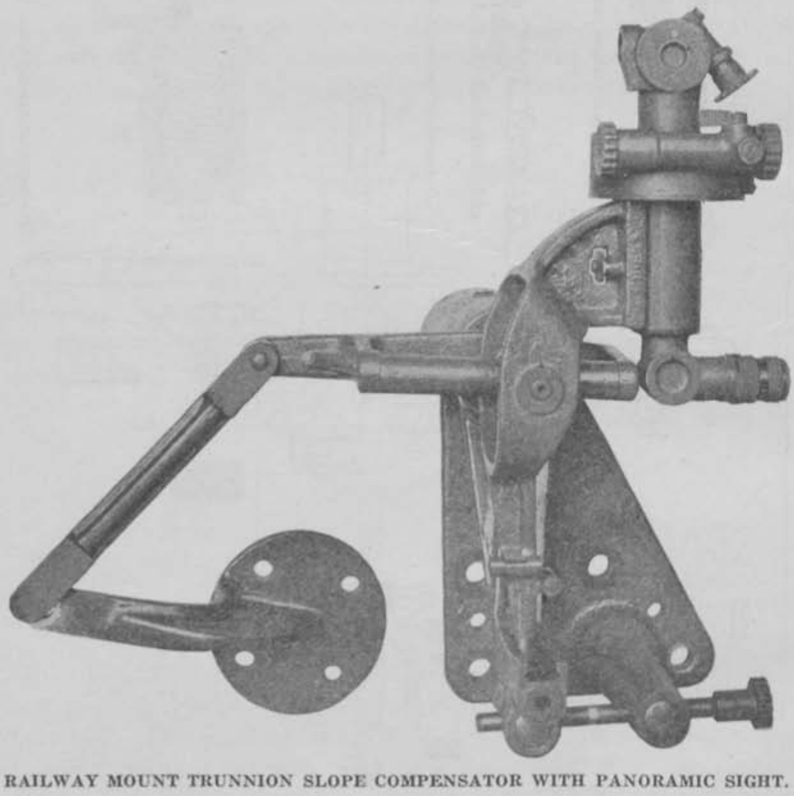
PLATE 94.



PANORAMIC TELESCOPE ON TRUNNION SLOPE COMPENSATOR OF THE QUADRANT TYPE, FOR USE ON FIELD CARRIAGES.

188. It was early recognized that if the axis of the trunnions is not horizontal the angle laid off on the tangent sight does not represent the angle of elevation of the axis of the gun. It was for this reason that tangent sights were so long in coming into general use in the Navy. This condition does not apply in the cases of fixed seacoast carriages, because the carriage is set so as to place the axis of the trunnions horizontal. It does apply, however, with guns on railway and wheeled field carriages. One early form of mechanism

PLATE 95.



RAILWAY MOUNT TRUNNION SLOPE COMPENSATOR WITH PANORAMIC SIGHT.

provided to compensate for the slope of the trunnions is shown in Plate 93. In this case loose rings were provided on the breech and muzzle of the gun to take the tangent and dispart sights. Each was provided with a hinged plate and plumb line on the bottom and could be rotated until the plumb line coincided with a line scratched on the hinged plate. The sights were then in the vertical plane through the axis of the gun. This mechanism has been refined to that shown in Plate 94 for field guns and to that shown in Plate 95 for railway mounts. In this latter case the sight is mounted on a

holder that is carried by a cross, which in turn is carried in a fork on the end of a shaft that is always parallel to the gun trunnions. The gun trunnion is connected by a link with this fork. One leg of the cross corresponds to the axis of the gun and is always parallel to it. The gun is elevated to the approximate degree, and the sight holder then leveled so that the cross leg of the cross is horizontal. The sight is then in a vertical plane that is parallel to a vertical plane through the axis of the gun, and a deflection laid off by means of the sight will point the axis of the gun in the proper direction. The reader is referred to section 6 of Volume I of Railway Artillery for further information on sights and the use of the device known as an aiming rule.

same time carry sufficient explosive to do serious damage after it has pierced the plate. Since we had had the opportunity to test the effect of a 2,400-pound projectile for piercing and destruction, and had found it satisfactory, this same weight was somewhat arbitrarily chosen for use with the new gun.

193. *Gun length.*—In determining the range to be secured the maximum attainable was of course desired. This depends upon the initial velocity and elevation, hence the immediate consideration of the maximum possible and practicable length for the gun and the maximum safe powder pressure. The maximum safe powder pressure with the type of powder that we have been using—that is, a single-base nitrocellulose—is approximately 40,000 pounds per square inch. Greater pressures have been secured without detonation of the powder, but it has not seemed wise either from the consideration of the strength of the gun or the risk of detonation of the powder to go higher than the 40,000. Turning to the matter of the length of the gun, it was found that the largest forgings that could be handled easily with available facilities and then machined at Watervliet Arsenal with present machine tools would be those of approximately a 50-caliber gun. It might have been made 51 or 49, but caliber lengths have generally been set in increments of 5, hence our guns of 40, 45, and 50 caliber lengths. The factors of powder pressure and gun lengths were decided then more by limitations than by desires. The range that seemed possible from this maximum pressure and length was 52,000 yards. Test has since proved this attainable.

194. *Type of gun.*—The next point for decision in the gun was whether it should be built up entirely of tubes and hoops of steel or be wound with wire as a substitute for some of the hoops. Here again limitations played a deciding part. The weight of a 50-caliber built-up gun would be so great as to require an unusually heavy carriage and would force upon the carriage designers problems that might in the end prove very difficult of solution. The recoil and recuperator mechanism, elevating mechanism, and traversing mechanism would all be seriously loaded by so heavy a gun. If, on the other hand, it were possible to construct the gun on the principle of winding it with wire, it would be lighter and the loads imposed on the above mechanism would be materially less. Investigation seemed to indicate that the guns could be made with the use of wire, and this type was therefore selected.

195. *Breech mechanism.*—Study of the several breech mechanism in use lead quickly to the conclusion that the mechanism in use on the Navy 14-inch guns, comprising a stepped-thread block swinging down practically in a vertically plane, would be the best that could be used. The block of the 14-inch gun swings to the side of the vertical because of limitations in ship's turrets. There was no reason

why it could not swing vertically down in this case, so this design was selected. The stepped-thread screw is opened or locked through so small degree of rotation and at the same time has a greater percentage of contact than the interrupted thread screw. It has served with entire satisfaction in the Navy, hence there was no doubt of its service on these proposed guns.

196. This practically completes the initial requirements. They comprise a 2,400-pound projectile, a gun length of 50 calibers, the wire-wound type of construction, and the Welin stepped-thread drop-breech mechanism. The initial velocity that is attainable with a maximum powder pressure of 38,000 pounds is 2,700 feet per second. This gives a maximum range of about 52,000 yards at an elevation of 53 degrees.

CARRIAGE.

197. *Type.*—In deciding upon the type and characteristics of the carriage one assumes that the question for decision was between the disappearing and barbette type and the extent of elevation that should be provided for the gun. It has been mentioned that a program had been initiated in 1916 for the construction of a number of disappearing carriages for guns of the design under discussion. These carriages, Plate 176, are of the typical Buffington-Crozier design, but a modification was made in the elevating mechanism to provide for a maximum elevation of 30 degrees. Experience of the war, well under way at that time, showed very clearly that such a gun as this is to a certain extent wasted on a carriage which does not provide greater elevation than 30 degrees. One of the 14-inch guns used on a British railway mount in 1918 gained an extra 100 yards in range between 46 degrees and 47 degrees elevation, the maximum range attainable at the service muzzle velocity being at the elevation of 47 degrees. It is plain to see, then, that the limitations of the disappearing carriage, in which extreme difficulty was experienced in providing even 30 degrees, so legislated against it as to practically rule it out of existence. The program of construction of the disappearing carriages was therefore discontinued and the barbette carriage was the natural conclusion as the only alternate. The decision to use this type of carriage instead of the disappearing carriage was reached in 1918, but one of the requirements of prime importance—that is, the extent of elevation to be provided for in this carriage—was not decided until the spring of 1920.

198. *Elevation.*—A discussion of the arguments considered which resulted in the provision of so extreme an elevation as 65 degrees for a gun of 50-caliber length may be of interest. It has been commonly understood that cannon of mortar and howitzer length—that is,

under approximately 25 calibers—were generally to be used for high-angle fire—that is, at targets against which a maximum plunging fire is desired; and, on the other hand, that cannon of greater length than from 25 to 30 calibers were to be used as the low-angle or direct-fire cannon where the chief desire was to reach the target. The only consideration in this latter case was to use for each particular target the minimum powder charge that would permit reaching that target with the maximum elevation computed for that powder charge. Operation on this plan would reduce the wear of the gun to the minimum. This scheme of operation, perhaps, applies to service in land warfare rather than to service in seacoast fortifications. In the case of seacoast fortifications, one of two things is desired. Either the projectile is to be dropped vertically on the deck of the boat with as great a velocity as possible, or it is to be projected against the side of the boat with sufficient velocity to piece the armor. The question that came up for decision in connection with this very long gun then was: Is it profitable and feasible to use a long gun for high-angle fire? It was certainly desirable to provide sufficient elevation in the carriage to attain the maximum range of the gun at the muzzle velocity according to which the gun had been designed. Since so many unusual things have taken place during the war and so many practices that had been thought either unwise or impossible have been proved both desirable and efficient, it was decided that if no particular disadvantages would result and it were found possible, this gun and carriage should be provided with mortar elevation—that is, 65 degrees. It was not certain when this was decided upon that it could be attained, but at least it was passed on to the designers as a goal to be attained if possible.

199. Further than the above, it was difficult to make any specifications except of a general character. Experience with hydropneumatic recoil mechanisms had shown that this was probably the only type of mechanism that would function with satisfaction. A decision to make use of this mechanism therefore does not involve any arguments pro and con. The decision with reference to the type of traversing mechanism again did not involve much argument. Before the designers had set to work on this part of the mechanism it had been learned that the carriage of the long-range gun which the Germans used in shelling Paris had been mounted on a ball bearing using 112 8-inch steel balls, the bearing being about 28 feet in diameter. All of our larger seacoast guns as well as the turrets on battleships had been mounted on conical roller bearings, and since these bearings had been found entirely satisfactory so far as functioning was concerned, it was thought best not to risk an ex-

periment with so valuable a gun as this in trying the ball bearing, which is in common use in German coast carriages and ships' turrets.

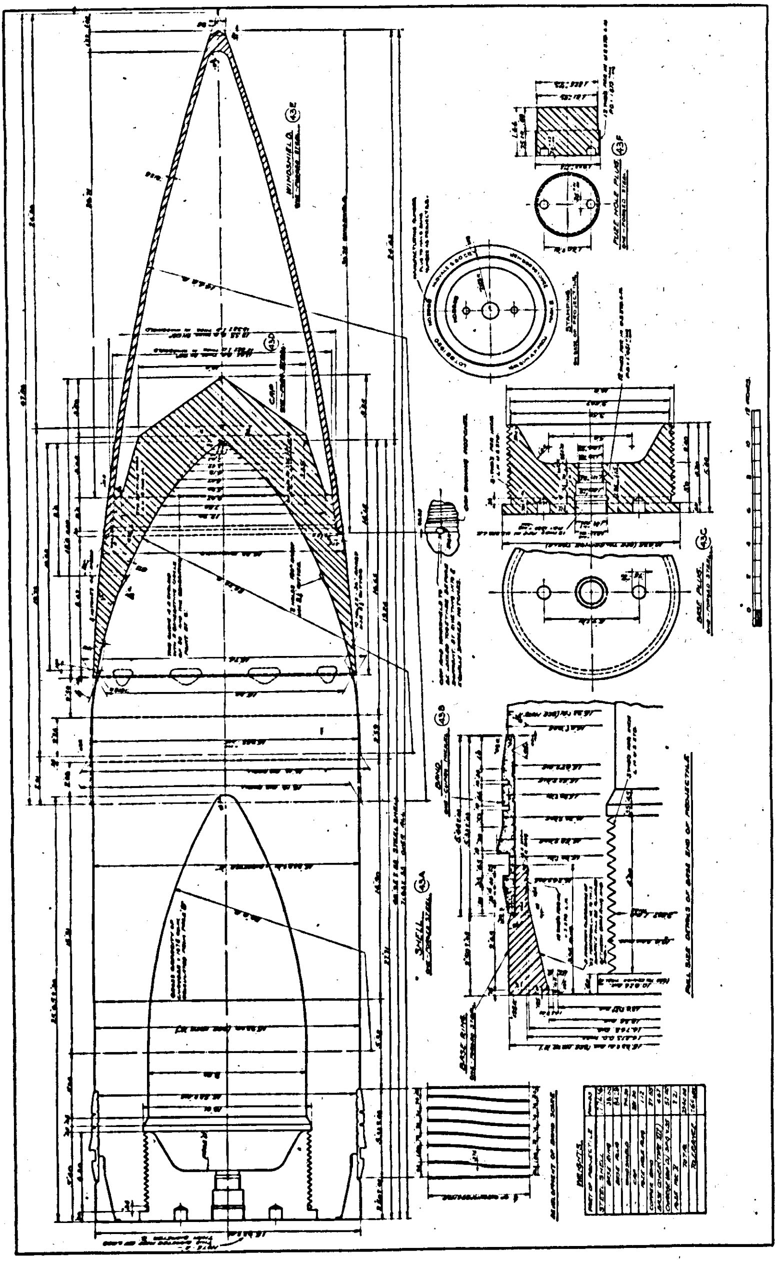
200. We may now add to the requirements set up for the gun as mentioned in paragraphs 193–194 the requirements just outlined for the carriage—that is, by the process of elimination, the carriage was to be of the barbette type, for the sake of experiment the elevation was to be 65 degrees, and to follow precedent the traversing mechanism was to be of the roller type and the recoil mechanism of the hydropneumatic type. In the case of the elevating and traversing mechanisms, it was decided that worm gears should not be used and that provision should be made for operation both by hand and power, the question as to how the power was to be applied being left to investigation on the part of the designing department.

DESIGN AND MANUFACTURE.

201. *Projectile.*—The processes involved in the designing and manufacturing of the projectile, which, by the way, had already been in use and therefore was not a problem necessarily considered in the design and construction of this distinct piece of ordnance, are perhaps relatively simple compared with those of the gun and the carriage. It was understood that this projectile was to have the capacity for piercing the thickest armor in use on battleships and was to contain sufficient explosive to do effective damage after it had passed through the armor. Experiments with projectiles made of all the various alloys of steel had shown that those composed of chrome-nickel have the greatest power to penetrate the hardened steel armor as well as to carry the maximum of explosive, approximately 2.5 per cent of the total weight. This means that steel of this alloy possesses such a tensile strength when properly heat treated and hardness of the point on special treatment as to enable the projectile to be made with the maximum cavity or the minimum thickness of wall and safely withstand the stresses resulting from the pressure on the base of the projectile tending to accelerate its linear velocity, the tangential force operating on its circumference through the copper band tending to accelerate its velocity of rotation, and last and most important, the terrific stresses developed on impact with the armor.

202. Should the strength of the projectile not be sufficient to withstand the stresses set up by these forces, it would break in the gun or swell, and cause a premature explosion or other serious damage to the gun, or shatter on impact with the armor. The projectile of this material and designed to withstand the stresses mentioned is shown in Plate 96. It was provided with a single copper rotating band at the rear, because experiments conducted through

PLATE 96.

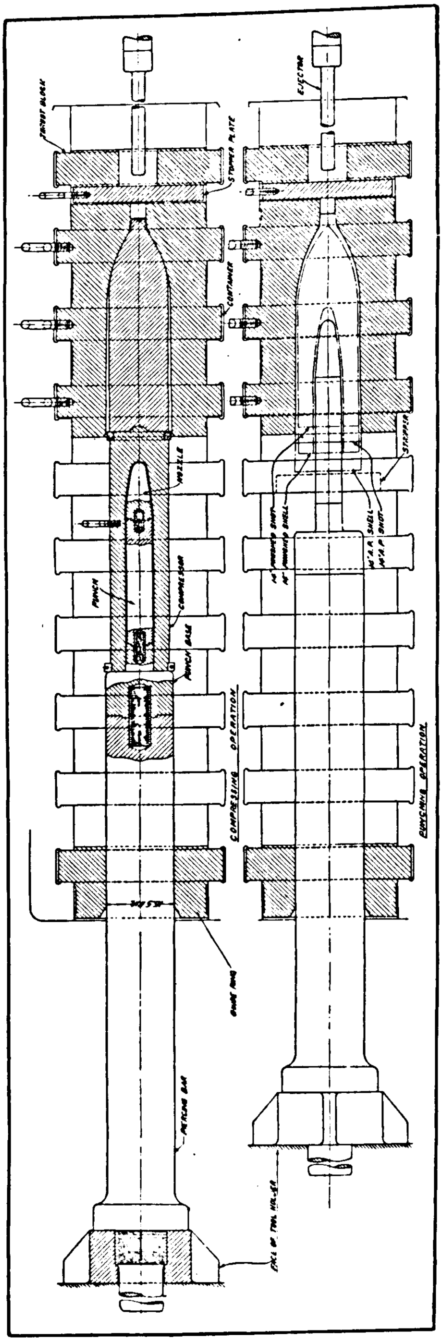


MODERN ARMOR-PIERCING PROJECTILE FOR 16-INCH 50-CALIBER GUN.

a period of the last 40 years have shown this to be the best design, and the profile of the copper band was designed likewise to conform to that found most efficient by experiments. It will be observed that the rear of the copper band is so designed as to serve both for the purpose of rotating as well as checking the powder gases. In such a projectile it is necessary, of course, to place the fuse in a plug screwed into the base of the projectile itself. The cavity has been made of the maximum size compatible with the stresses that will be set up, and has likewise been so shaped and placed as to give to all parts of the projectile sufficient strength to stand all of the stresses that will be set up in it, either in the gun or in piercing the armor.

203. *Manufacturing.*—Steel of the desired alloy is cast in ingot form and forged under a hydraulic press until it has attained the desired homogeneity. It is then heated and pierced by simply pushing into it

PLATE 97.



200 TON HYDRO. PRESS FOR SHAPING AND PUNCHING SHELLS.

a mandril of hard steel, Plate 97. The resulting forging with the pierced cavity is then machined on a lathe with the exterior and cavity conforming to the mathematical design shown in the finished projectile, Plate 96. The forging, by the way, is given sufficient heat treating before machining to insure that there are no serious internal stresses that will deform the projectile during the machining processes. When the machine work has been finished, the point is then hardened in oil and the copper rotating band placed around it and pressed into the groove machined for it by means of a hydraulic press. After the copper band has been machined the projectile is shipped to the ammunition arsenal, where it is filled with the desired high explosive and the base plug and the fuse inserted. It might be well to mention here a common practice with projectiles of this size in use in German coast defenses. With us it is the habit to pour the melted explosive into the cavity after the metal has been coated with lacquer to prevent contact between the explosive and the steel. This makes it difficult to remove the explosive and there is always the possibility of a chemical reaction between the explosive and the steel if the separating film should break down. It is the common practice in Germany to pour the explosive into a vulcanized fiber container of the exact shape of the shell cavity. The walls of this container are about one-sixteenth of an inch thick. The projectile and the explosive are then sent to the fortification separately, and if desired the explosive can be removed and other explosive inserted at any time.

204. *Gun.*—Before beginning with a description of the detailed procedure in the design of this gun, it may be well to mention a few of the principles involved in the construction of any multipiece gun and of the wire-wound type of multipiece gun. It has already been mentioned that in 1836 it was demonstrated that a homogeneous gun—that is, a gun made of solid material—soon reaches a limit of thickness beyond which additional thickness fails to give additional strength to resist tangential stress. Until that time it was the practice to increase the diameter of the cast guns to such proportions that the guns became very unwieldly. The metallurgist was likewise called upon for materials of high tensile strength, but when the metallurgist had reached the limit of his resources and cannon had become unwieldly in weight, it was necessary to have recourse to some other priniciple. Shortly afterwards it was demonstrated that dependence could not be placed in solid guns. A practice started in the fourteenth century with the great wrought-iron guns, which were made by first welding together a series of wrought-iron bars into a tube and then driving or shrinking onto this tube a series of rings, likewise of wrought iron, was revived in the form of shrinking over the breech end of the gun or of casting inside of the breech end, a wrought-iron or steel cylinder formed by coiling

a long wrought-iron bar of square section about a mandril and welding it into the cylinder. This served to increase the strength of the guns beyond that of the cast guns.

205. Between 1850 and 1860 Sir William Armstrong further developed the principle of constructing guns of steel or wrought-iron tubes and hoops shrunk on, and at Woolwich Arsenal the practice of constructing a gun by winding wire about the tube was started and developed to quite a degree. It will be remembered that Professor Treadwell, an American, claimed credit for having discovered the principle of winding the tube with an envelope of wire, although there were several other claimants to the original conception. It was in about 1850 that the theory of this construction was worked out to a fairly accurate degree. The greatest handicap under which the designers and manufacturers labored, prior to the discovery of the weakness of the monopiece gun, was that they could depend only upon the strength of the metal between the limits of no stress and the elastic limit in tension. The construction of a gun either under the principle of shrinking a series of hoops over the tube or of winding many layers of wire about it, has for its merit the practical doubling of the capacity of the gun for standing an internal pressure tending to rupture the inner layers of the tube. If we take, for example, the case of the gun wound with wire, the tube initially is under no stress, either tension or compression, if it has received proper heat treatment. The wire is wound on either at a constant tension or at an increasing tension, with the purpose of compressing the metal of the tube practically to its elastic limit. Hoops are then shrunk on, and the resulting gun has a strength to resist the tendency of an internal pressure to burst the tube equal now to the range between the elastic limit in compression and the elastic limit in tension. Having evolved this principle, it seems that in terms of construction at least we have reached a limit in capacity to withstand pressure, and we can make progress in the construction of guns to withstand greater pressure only through the assistance of the metallurgist in furnishing us with materials having greater tensile strength. The alloy steels which are drawn into the wire for winding these guns has a higher tensile strength than the large forgings used in making tubes, jackets, and hoops. As other alloys of greater strength are discovered we can either reduce the diameter of our guns—that is, reduce the thickness of the walls—or we can leave the walls as they are and increase the powder pressure and the velocity of the projectile. There may be some promise for advancement of this character in the rather new zirconium alloy of steel. Zirconium steel has not yet been produced in sufficiently large quantities to permit of

that exhaustive testing that is desirable before being used in guns of such caliber. It seems to promise well, both in increased tensile strength and increased hardness. Some specimens of this alloy that have just been tested are reported to have shown a tensile strength of 400,000 pounds per square inch. Another report on a hardness test of a plate 12 inches square heat treated with apparent uniformity, gives variations in hardness of as much as 60 and 100, Brinnel test.

206. Since the mathematical discussion of the principles of design of the various parts of a gun of this character are so thoroughly and elaborately worked out in "Ordnance and Gunnery" by Lissack, and "Stresses in Wire Wrapped Guns" by Ruggles, no such discussion will be given here. Instead the space will be devoted to a more general discussion of procedure in designing and a discussion of the procedure in manufacturing and assembling. The student is referred to the above texts for the mathematical discussions.

207. *Design—Gun.*—Starting with the requirements already enumerated for the gun a designer develops the following additional elements which are to be used in developing the various curves of pressure, velocity, etc., which will determine the thickness of the various elements of his gun at their various points:

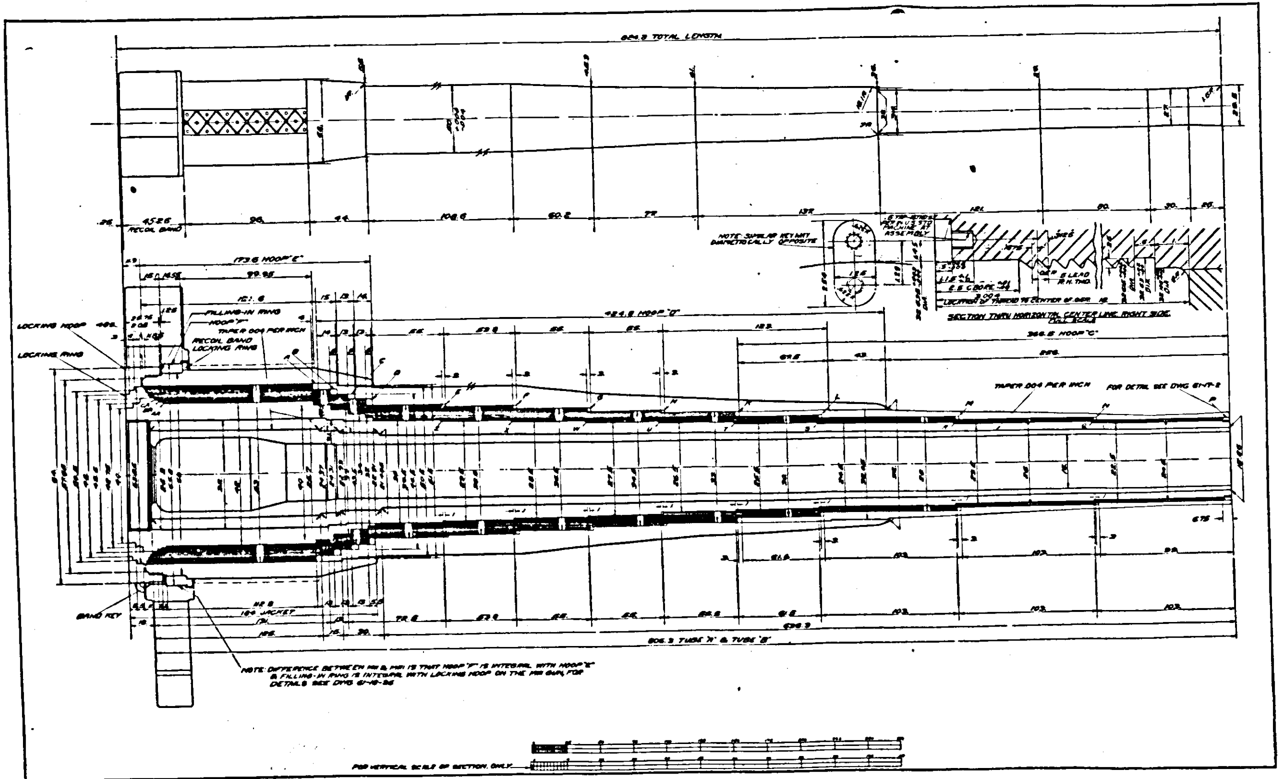
Elements of the gun.

Length of gun in calibers[1]		50
Weight of projectile[1]	pounds	2, 400
Weight of powder charge	do	850
Travel of the projectile	inches	684. 6
Volume of the powder chamber	cubic inches	40, 000
Density of loading		0. 5882
Maximum pressure[1]	pounds per square inch	38, 000
Muzzle velocity[1]	feet per second	2, 700
Muzzle energy	foot-tons	121, 430

208. It has been the common practice in the construction of this type of gun to use two tubes, the inner termed an A tube and the next a B tube. In assembling, the jacket is shrunk on over the B tube at the rear. Over the length of this unit of tube and jacket, from the locking ring at the breech to the P ring at the muzzle, is wound an envelope of wire. This envelope is composed of a larger number of layers at the breech than at the muzzle, Plate 99. The wire, approximately one-tenth of an inch square or one one-hundredth of a square inch in area, is wound with a pull of 5,000 pounds, as indicated by the gauge on the winding machine; thus maintaining a uniform tension stress in the wire of 50,000 pounds per square inch. Over this envelope of wire the outside hoops C, D, and E, with the various filler and locking rings are shrunk on. The gun, together

[1] Previously determined.

PLATE 99.



DIMENSIONED ASSEMBLY OF 16-INCH 50-CALIBER GUN. THE VERTICAL SCALE OF THE LOWER VIEW IS TWO AND ONE-HALF TIMES THE HORIZONTAL.

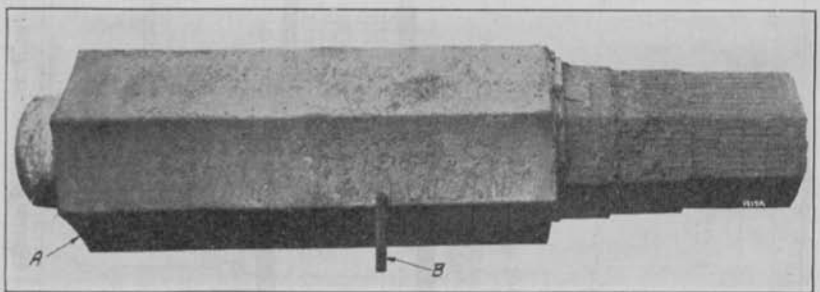
extremely long guns of this type is a serious fault. The first of these guns showed a droop of approximately 0.6 inch. On firing, the muzzle vibrates approximately 3 inches, and it can readily be imagined that the terrific stresses set up in all members, except possibly the wire, by this vibration will play a considerable part in the

PLATE 100.

BILLETS FOR TUBES, HOOPS, AND RINGS.

rate of the wear of the gun. Guns wear most rapidly at the origin of rifling and at the muzzle. The vibration of course has nothing to do with the rate of wear at the muzzle, and perhaps since the wear at the origin is usually the factor which condemns the gun, the lack of rigidity and excessive vibration may not be a fatal fault.

PLATE 101.

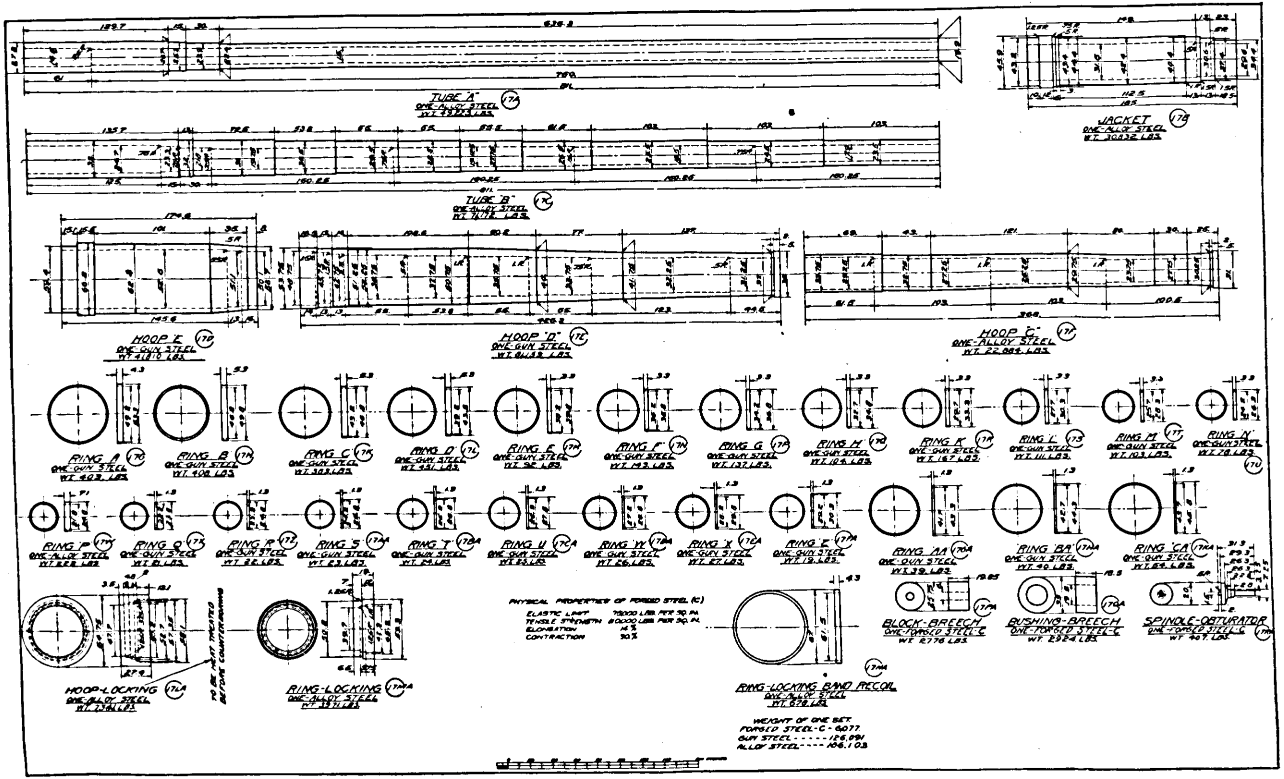


RELATIVE SIZES OF TWO 16-INCH GUN INGOTS.

Plate 99 gives a section of the gun assembled and shows the dimensions of the various parts.

211. *Construction—Billets.*—The total number of parts composing the design that has just been discussed is 38. The parts involving the greatest difficulty in manufacture are the A and B tubes,

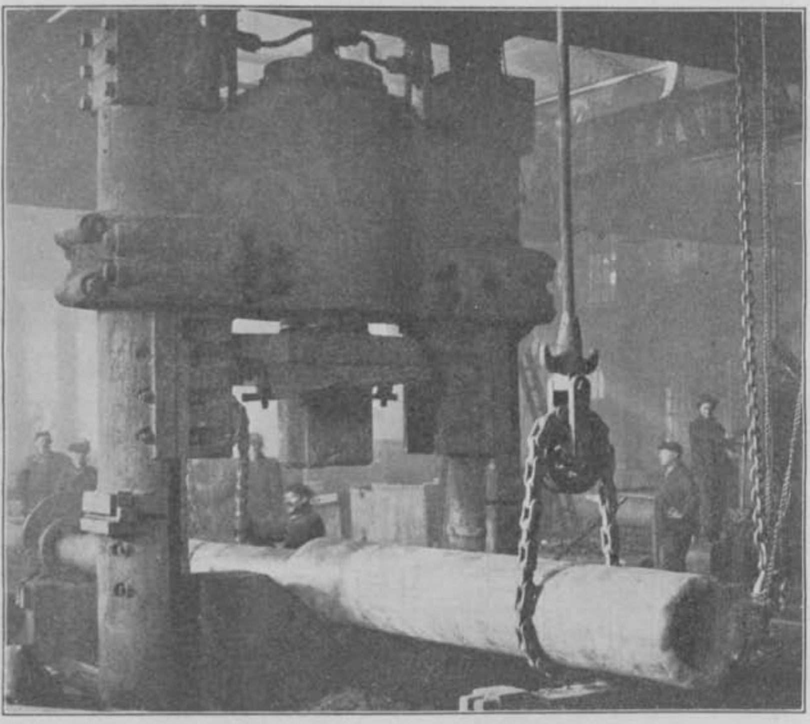
PLATE 102.



FORGING COMPONENTS OF THE 16-INCH 50-CALIBER GUN.

the jacket, and hoops C, D, and E. The principal difficulties are experienced of course with the A and B tubes. These tubes originate in cast-steel billets, Plates 100 and 101, of such a length that it is possible to cut from each end a considerable portion to avoid the possibility of blowholes or other faults in the steel. The original billet from which the A tube is made weighed approximately 194,000 pounds. The billet from which the B tube was made weighed 276,000 pounds. Below is a table showing the weights of the billets from which the

PLATE 103.



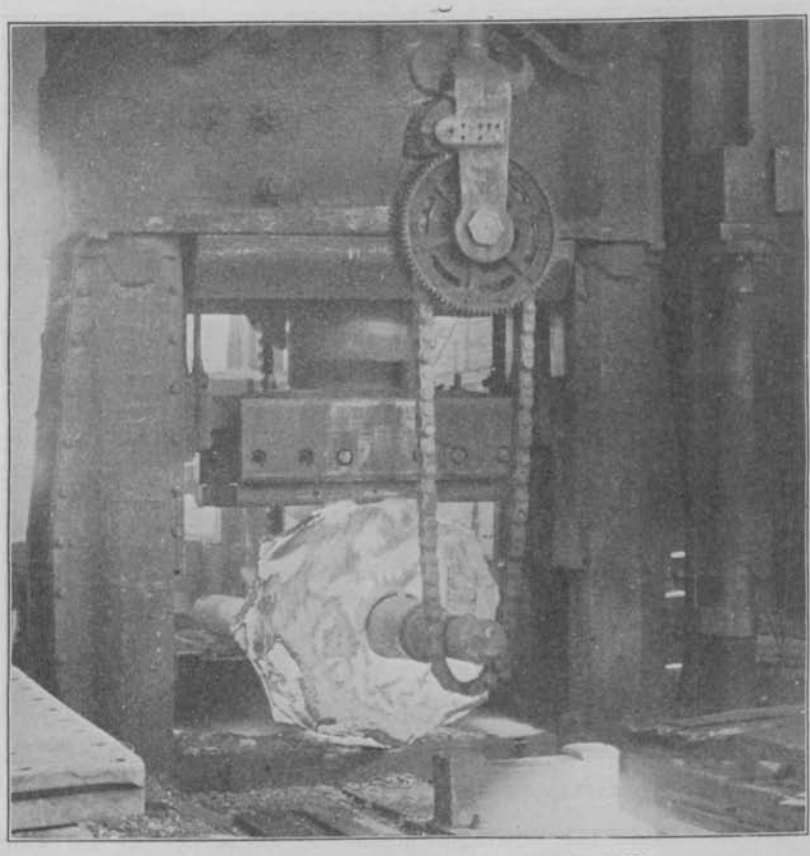
FORGING OVER A MANDRIL WITH HYDRAULIC PRESS.

various larger components were made. It is necessary of course to provide a separate billet for the A and B tubes, the jacket, hoops C, D, and E, and the trunnion hoop. In the case of the locking rings, etc., illustrated on Plate 102, which gives the final dimensions of each of the 38 parts except the breech, it is not necessary to supply a separate billet and forging for each of these rings. Quite a number of rings can be cut from the same forging originating in a single billet. The total number of ingots required is 10, assuming that a number of rings can be made from one ingot.

Weights of forgings and ingots.

Part.	Ingot.	Forging.
	Pounds.	*Pounds.*
A tube	194,112	48,528
B tube	275,992	68,998
C hoop	91,536	22,884
D hoop	315,532	78,883
E hoop	162,508	40,627
Jacket	123,328	30,832
Breechblock	10,768	2,692

PLATE 104.



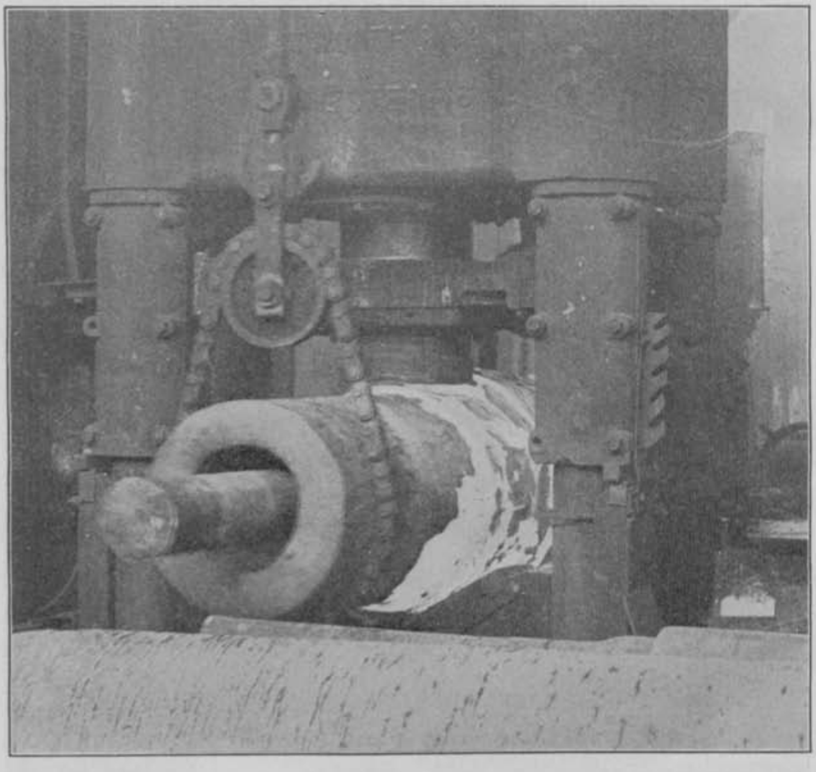
HOT HOOP BILLET ON MANDRIL FOR FORGING.

212. *Forging.*—Returning to the A tube, for example, the portion of the billet remaining after the ends are removed weighed approximately 126,000 pounds. This remaining billet is then forged under a hydraulic press, Plates 103, 104, 105, 106, and 107, to a total length greater than that required for the gun and the ends removed to insure the production of tubes without faults. Before being machined the

tube is given a thorough heat treatment to relieve the strains set up in the forging, Plates 108, 109, 110, and 111.

213. *Machining.*—The tube is then placed in a gun lathe similar to that shown in Plate 112 and turned at various points in its length for the placing of machine rests and the entire exterior turned to approximately its final dimensions. After the exterior is turned so that it becomes a true cylinder it can be supported at numerous places on its length by the proper machine rests, Plate 113, the inside is

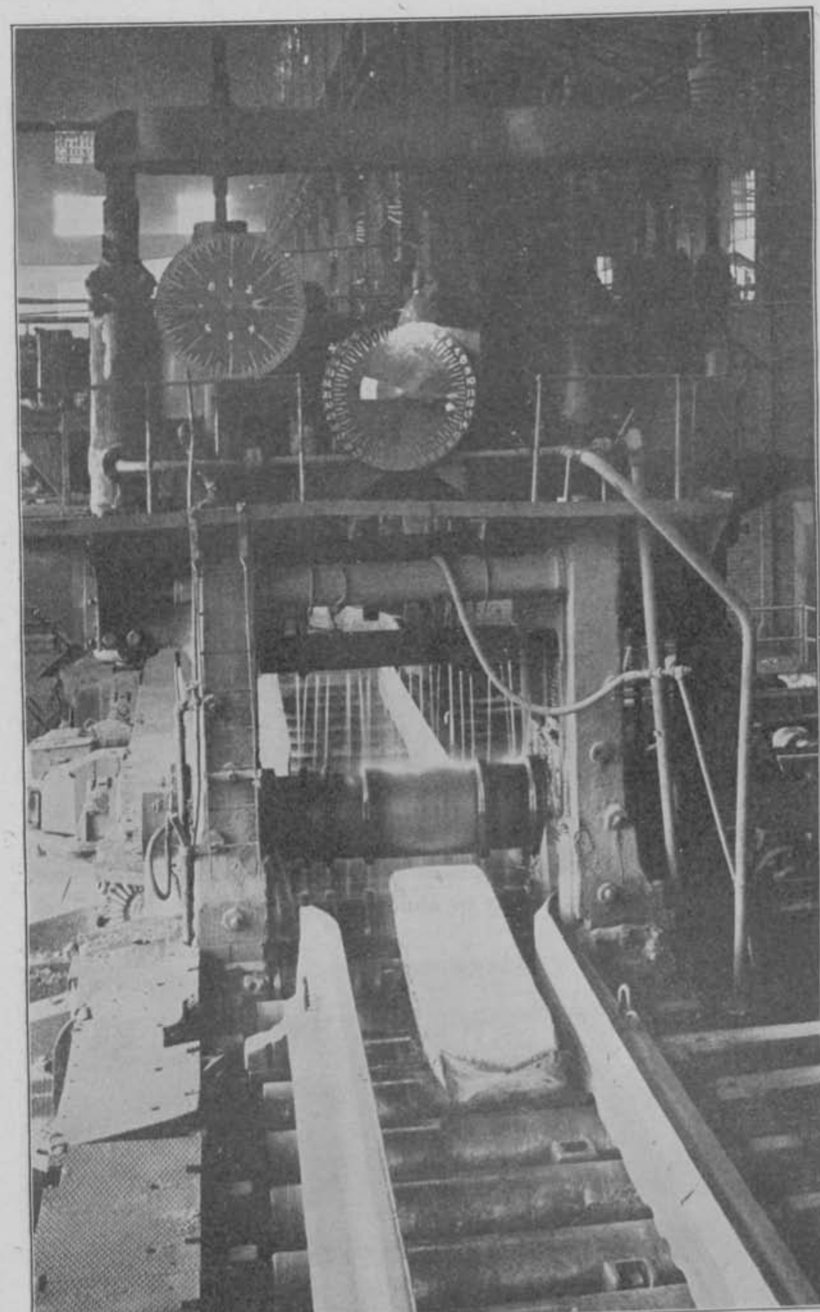
PLATE 105.



JACKET BILLET IN PROCESS OF FORGING.

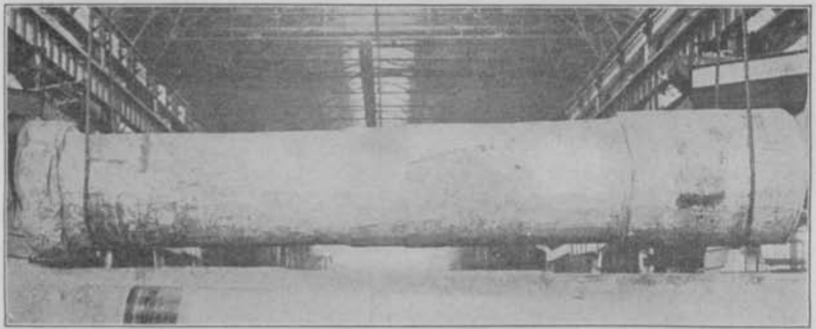
bored out, Plate 114, through the use of a boring bar carrying "packed" bits. In the boring operation the tool or boring bar may have a tendency to deviate from the true axis of the tube, although this is not so likely as a consequence of the scheme of packing the bits. The packed bits are cylinders of hardwood on frames carrying two or more tools. The wood is a few thousandths of an inch larger in diameter than the hole to be cut, so that by its forcing the tools are held rigidly and accurately. Frequent inspection is necessary

PLATE 106.



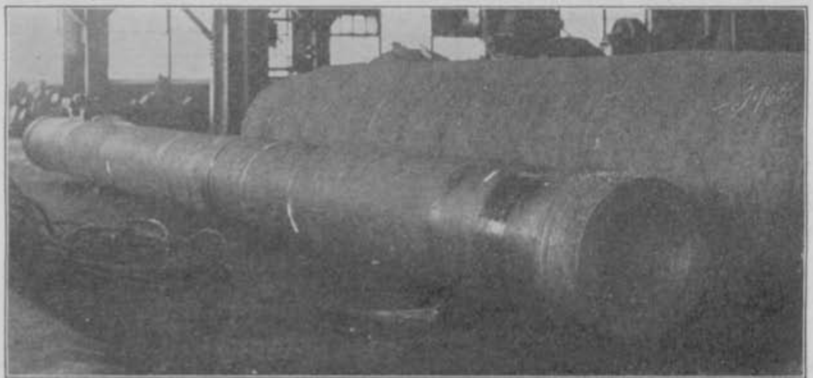
ROLLING A STEEL BILLET FOR A GUN PART.

PLATE 107.



FINISHED FORGING OF JACKET.

PLATE 108.



TUBE AND JACKET IN ROUGH TURNED STATE.

PLATE 109.

CONVEYING HALF-FINISHED PIECE INTO THE OVEN AT RIGHT FOR ANNEALING.

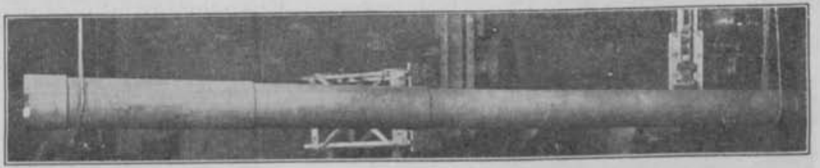
during the boring to see that the hole is true. An indicator similar to that shown in Plate 115 is used for this purpose and an eccentricity

PLATE 110.

SHOWS ENDS OF TUBE AND JACKET WITH SPECIMENS REMOVED FOR TESTING THE PHYSICAL CHARACTERISTICS OF THE STEEL.

of one-thousandth of an inch is easily detected. Liners of thin metal are put between the stem of the cutting bit and the socket in the end

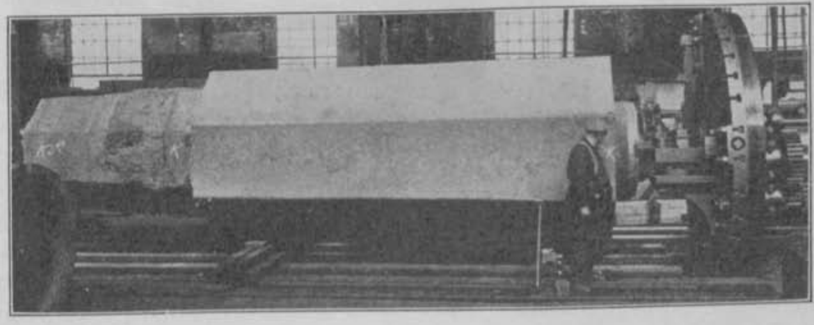
PLATE 111.



ROUGH-TURNED TUBE.

of the bar until the bits are so placed as to eliminate eccentricities in boring. The tube is likewise frequently star gauged, Plate 116, to

PLATE 112.

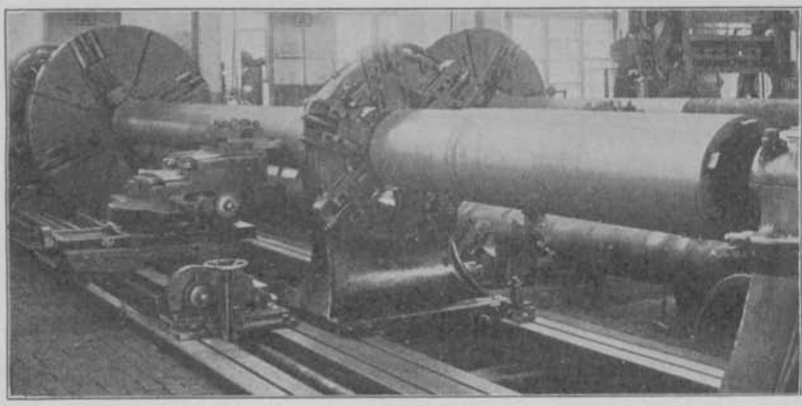


INGOT ON LATHE.

determine whether the hole is perfectly cylindrical and of the proper and uniform diameter. It is customary to make from three to four

cuts through the bore so that eccentricities appearing in the first cut may be eliminated at least by the final cut. It is usual to make two

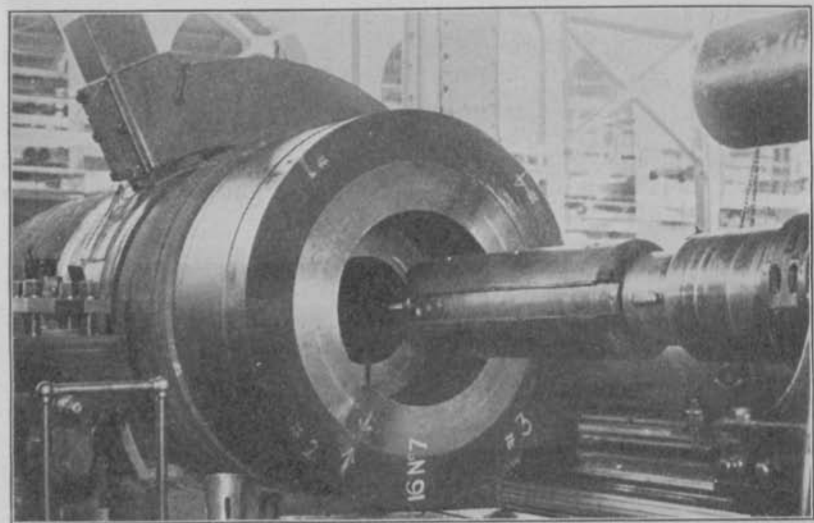
PLATE 113.



FINISH TURNING THE TUBE ON ENGINE LATHE.

rough cuts and two smoothing cuts. When the diameter of the bore varies, as is the case with nearly all of the tubes and hoops, the boring is of course done from the large end. First the initial uniform

PLATE 114.



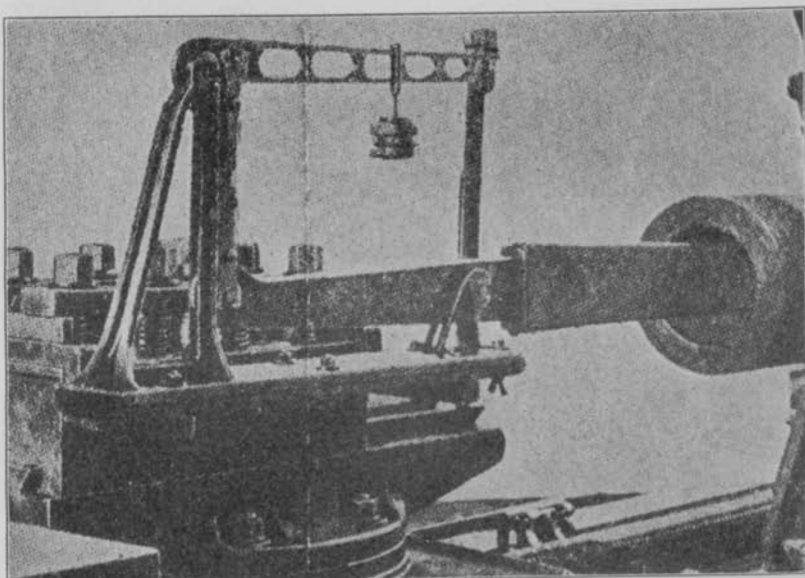
BORING THE POWDER CHAMBER WITH PACK-BIT.

cut throughout the tube is made and then the rough cut through the enlarged section. The larger diameter is then accurately bored out. A packed bit is next prepared with the forward end and tool set at

the diameter of the smaller hole to be cut, while the rear end is left at the larger diameter. This serves to center the smaller hole with the larger. In all of this boring the bits are kept well lubricated by oil forced into the bore.

214. *Assembling.*—The first step in the assembling of these finished parts involves the expanding of the jacket in an electric furnace or heater, Plate 117, and the slipping of it over the B tube to its proper position. During this operation the B tube is kept cool by forcing water through it. When the jacket is in place over the B tube it is cooled from the breech end forward by spraying with water. This is to insure its proper seating on B. On cooling

PLATE 115.

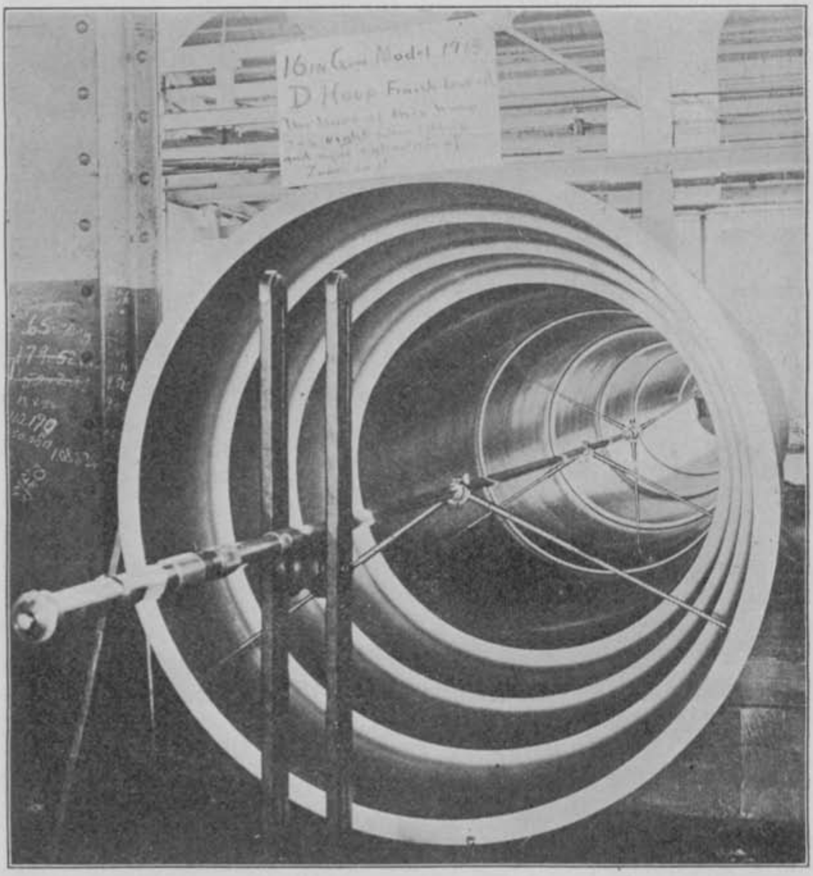


BORE CENTER INDICATOR.

it grips the B tube tightly, compressing it nearly to its elastic limit. These two assembled parts are then placed in the winding lathe and one section after another is wound with the square wire coming from a tension drum or mechanism which keeps it stressed constantly to the desired approximate 50,000 pounds per square inch. A greater number of layers of wire are required at the breech than at the muzzle because greater pressures are developed at the breech, therefore greater thickness of tube and hence more wire to compress this greater thickness to its elastic limit. When the desired number of layers of wire have been wound on in each section of the length, the wire is locked in a special locking groove in the locking ring and the wire throughout the entire length of the gun

surfaced by grinding just sufficiently to provide shrinkage surfaces. It may be found necessary to vary the inside diameter of the various hoops after the wire has been wound and surfaced, since it is practically impossible to predict what the exact diameter of any number of layers of wire will be. Hoops C, D, and E are then shrunk on, and the whole gun heated, slipped over, and shrunk onto the A tube, Plates 118 and 119. Any necessary surfacing or

PLATE 116.

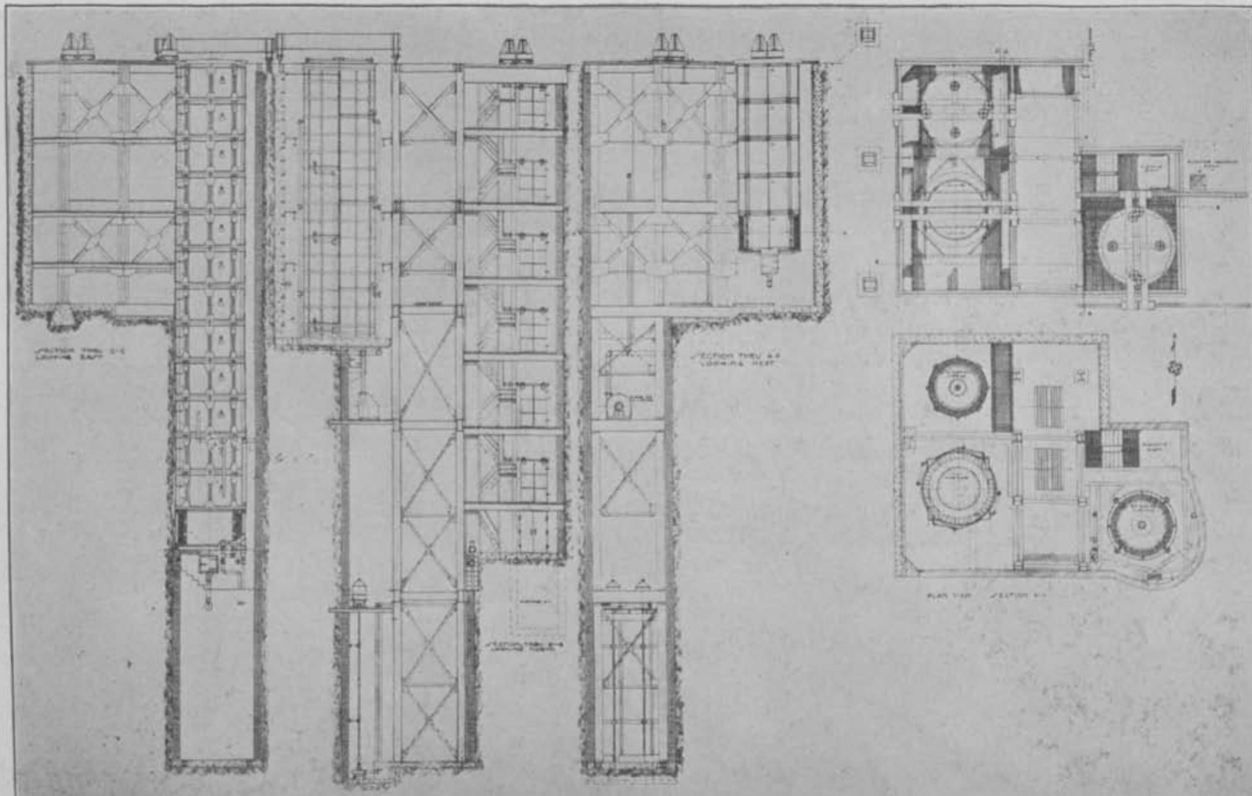


STAR GAUGING FOR ACCURACY OF BORING.

turning of the exterior of the assembled gun is now done, and on the completion of this machining the gun is ready to be rifled.

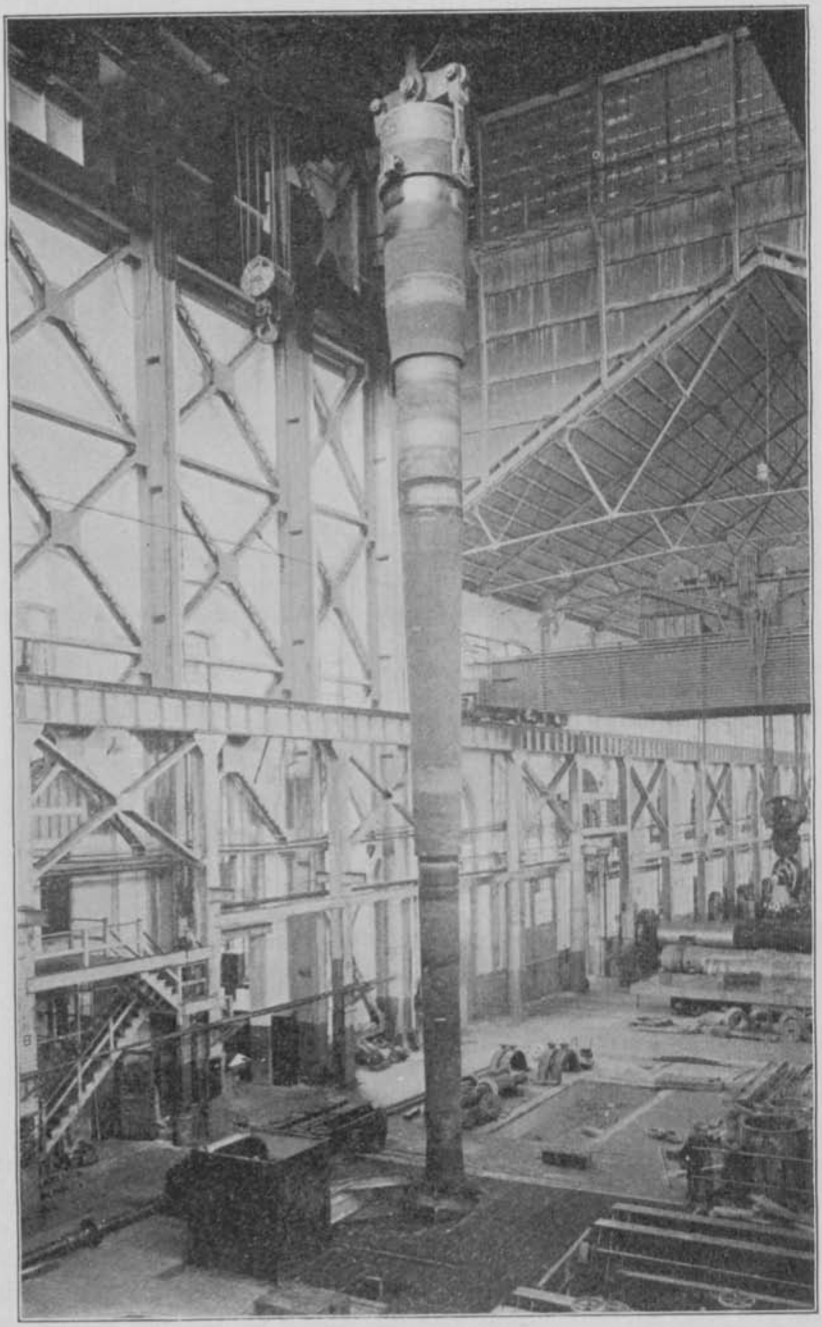
215. *Rifling.*—In the original mathematical design of the cannon it has been determined from the muzzle velocity and the weight of the projectile what velocity of rotation the projectile should have on leaving the gun to insure stability throughout its flight. This rate of rotation on leaving the muzzle of the gun is secured through

PLATE 117.

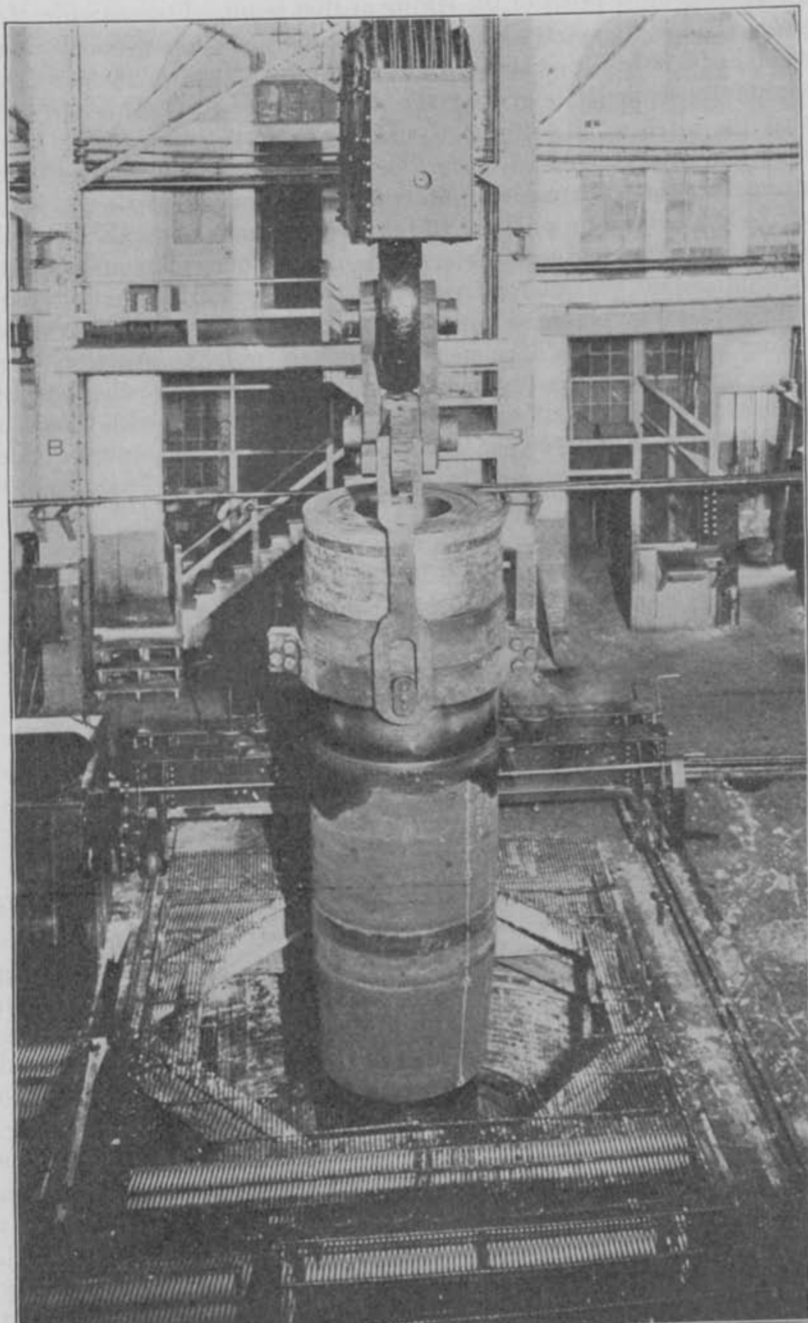


HEATING FURNACE FOR EXPANDING GUN PARTS FOR ASSEMBLING.

PLATE 118.



16-INCH GUN OVER SHRINK PIT OF FURNACE.



GUN LOWERED INTO PIT.

a certain definite pitch of the rifling at that point. For example, if a projectile is to leave the muzzle of the gun at a linear velocity per second of 2,700 feet, a rate of rotation of approximately 90 turns per second is required to give it the desired stability. This requires that the pitch of the rifling be such as to turn the projectile once in a linear travel of 31.25 feet. If it is desired to ease up the stresses in the gun resulting from the accelerating of the rotation of the projectile, the pitch of rifling may be made one-half as much at the origin as at the muzzle. This is a rather common practice. Assuming that the pitch of rifling is to be uniform, a template or rifling plate is prepared from a drawing made of the curve of rifling in the bore as developed on a plane surface. An iron template is constructed with one edge straight and the other cut to the developed curve of the rifling. For a uniform twist this is a straight line, Plate 120, at a constant angle to the straight side.

PLATE 120.

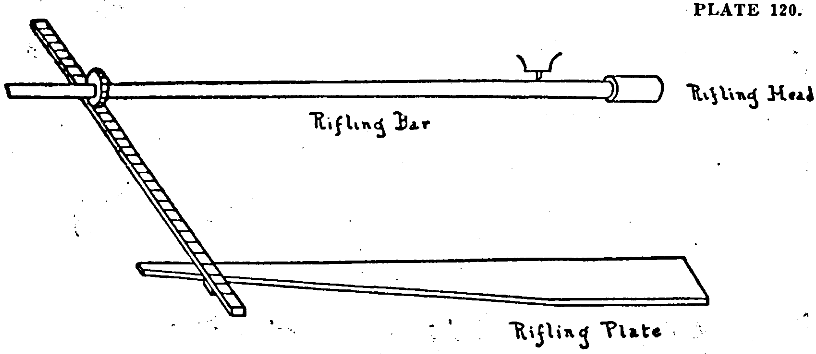


PLATE AND BAR MECHANISM FOR RIFLE GROOVE CUTTING.

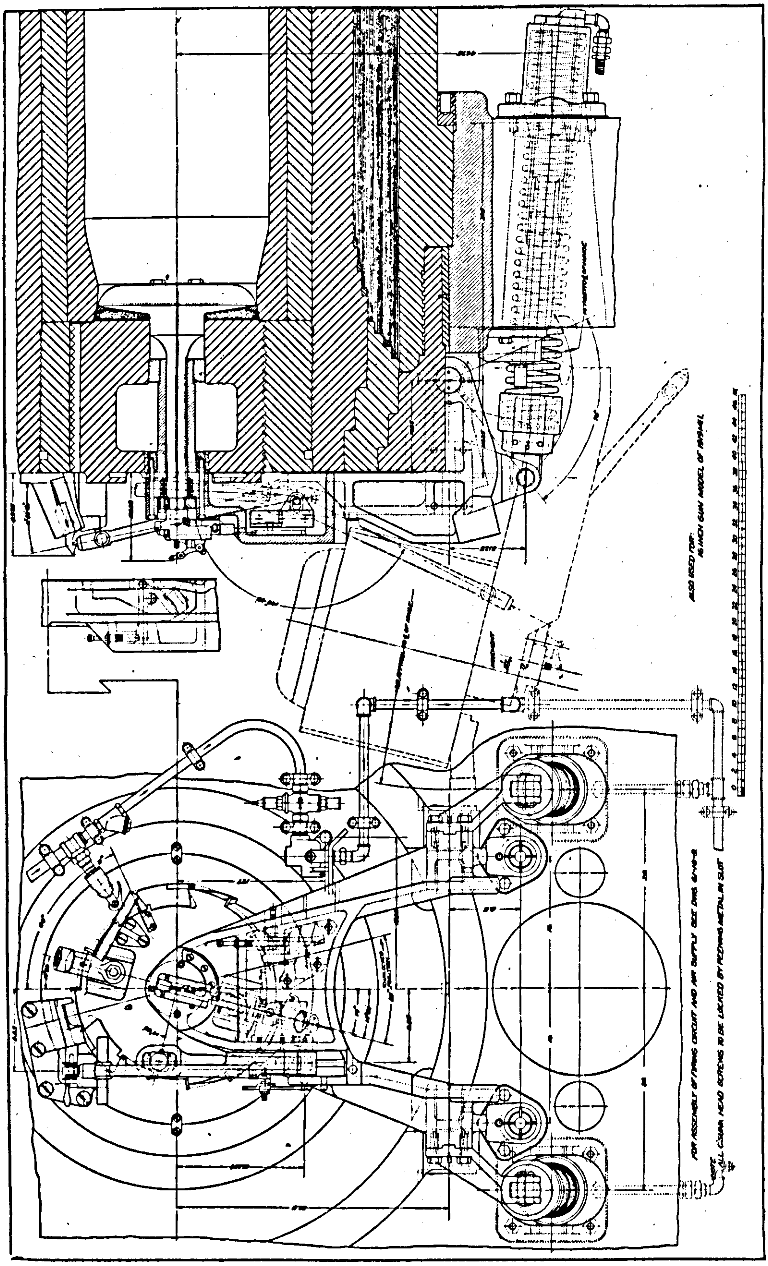
For rifling of an increasing pitch it is a curve. This template is secured to one side of the lathe used in cutting rifling bars and has pressed against its curved side a roller carried in an arm extending across the bedplate. The top of this arm is a rack which through a series of pinions, Plate 120, drives the head carrying the rifling bar. The cutting tool is stationary, and as the rifling bar is fed along it is turned the necessary amount to permit the tool to cut on its surface a curve identical with that desired in the rifling. This slot cut in the surface of the rifle bar is about 0.5 inch wide and 0.5 inch deep. After the rifling bar has been completed, a rifling head, containing four sets of cutting tools and somewhat similar in general construction to the packed bit already mentioned, is attached to the end of it. These tools can be set out separately or together by means of wedges controlled by screws on the front of the head. This cylinder, though attached to the front of the rifling bar, is capable of rotating about the axis of the bar and is

held in any one position by means of pins engaging in holes in the bar. Thus a series of four grooves can be cut through the gun, and on turning the head so that the pins engage in another set of holes the remaining grooves are cut. The gun is rifled from the muzzle end. Both gun and bar are placed in a special lathe or machine tool for this purpose, the gun being accurately centered with the axis of the boring bar. A lug is provided on the front rest of the boring bar which engages with the curve already cut is the bar through the use of the template. As the bar is forced forward by pressure from the rear it is compelled to rotate in proportion to the twist of this curve. Each set of three cutting tools comprises a plain rectangular grooving tool, a top profiling tool and a bottom profiling tool. The depth of cut on each passage of the head through the gun is about two one-thousandths of an inch. Thus it requires about 70 cuts to produce the desired final depth of rifling. The rifling head is provided with a bronze sleeve which centers the bar in the tube.

216. *Finishing.*—When all of the grooves have been cut, sometimes the powder chamber and the forcing cone at the forward end of the chamber are finish machined. The breech end of the gun is then finished for the reception of the breech mechanism and the gun placed in a lathe for the determination of the maximum and minimum droop. It is desired to so mount the gun on a carriage that it is in the position of minimum droop and likewise in a certain definite position with reference to its center of gravity. As soon as the point of minimum droop has been located and the necessary lines inscribed on the muzzle for bore sighting, the gun is balanced for the location of the trunnion band if such is to be used. In this case, since the gun is to be carried in a cradle, no trunnion band is provided. The counterweight, or recoil band as it is called in Ordnance parlance, that is finally slipped over and attached to the breech end of the gun is, to a certain extent, a part of the recoil mechanism, and for this reason will be considered a part of the cradle and carriage, although it is, of course, relatively integral with the gun.

217. *Breech mechanism.*—The breech mechanism, Plate 121, is composed of a single screw threaded to three different diameters with a fourth smaller unthreaded diameter. This is the Wellin type of breech block and has the double merit of permitting locking and releasing with a minimum turn and a maximum degree of contact and capacity for withstanding the stresses tending to shear the threads. This block is likewise made from an ingot weighing originally approximately 10,000 pounds. It is first forged to render the metal homogeneous, and is then machined on a lathe to the shape shown. It is attached to a hinge which is supported on

PLATE 121.



DROP-BLOCK TYPE BREECH MECHANISM OF THE 16-INCH 50-CALIBER GUN.

pins in the recoil band, Plate 160. In opening, this hinge drops vertically against spring cushions and the block is returned to its normal position through air pressure in a closing cylinder incorporated in the recoil band. The completed breechblock, Plate 121, is composed of the screw, a spindle with mushroom head, an obturating pad, and the hinge by which it is attached to the counterweight. In Plate 160 it will be observed that an automatic gas ejector of the type commonly used in the Navy has been provided to sweep out the gases from the gun.

218. The gun and breech may now be considered completed and ready for assembling with the carriage. It will be noted that no procedure of lapping or polishing of the bore of the gun after rifling has been mentioned. This was once a rather general practice, and is still to a certain extent. The use of a packed rifling head and a succession of cutting bits taking relatively light cuts each has been found to produce so good and clean a surface that further finishing has been found unnecessary.

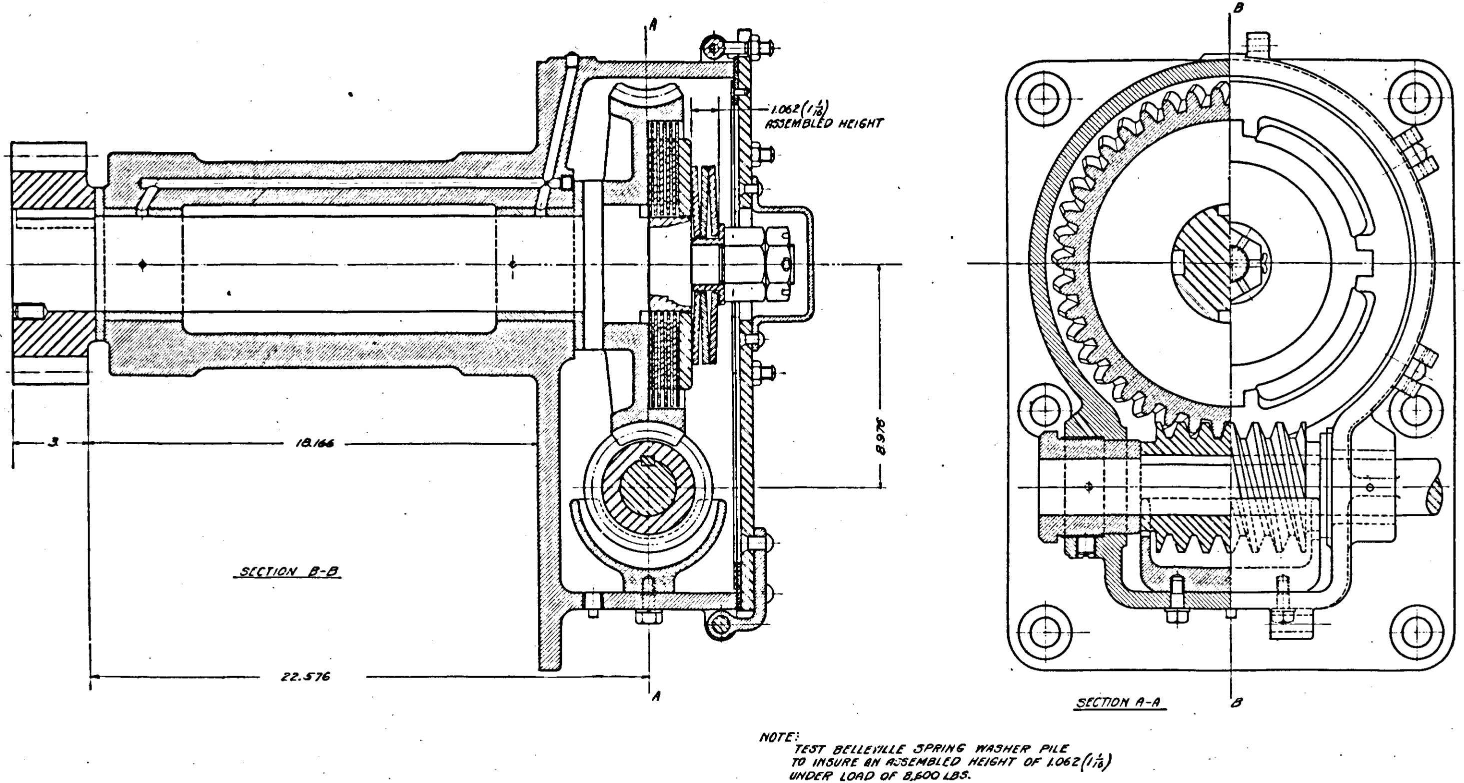
CARRIAGE.

219. *Characteristics.*—In considering the carriage as a whole only general requirements could be established before the matter of detailed design was taken up. It has been mentioned already that since the hydraulic recoil and pneumatic counter-recoil mechanisms had already proved satisfactory for somewhat similar guns and our designers had become familiar with the principles of design of these types of mechanism, and, further, since the gun to be handled was of such extreme weight as to make the use of springs by themselves very doubtful, the natural conclusion was to use the usual hydraulic cylinder for the recoil brake and the pneumatic mechanism for the recuperator.

220. In the case of the elevating mechanism, the one principle that was decided upon as a preliminary was to use a mechanism that did not include worms or worm wheels. Further, it was considered desirable to have a ratio of movement of the gun of 1° per turn of the handwheel, if this ratio would permit the desired fine final setting of the gun.

221. The elevating mechanisms of seacoast carriages constructed prior to the war and even early in the war practically all included a worm and worm wheel. The principal function of this combination was to serve as a lock against the shifting of the position of the gun in the vertical plane from any position where it was desired that it remain. Slip friction devices of the design shown in Plate 122 had commonly been provided in the worm of the elevating mechanism to avoid the breaking of the worm wheel or worm through the strain

PLATE 122.



SLIP FRICTION DEVICE OF THE MULTIPLE DISC TYPE WITH BELLEVILLE SPRINGS.

brought upon it when the gun is fired. It was always known that a large percentage of the power delivered through the hand-wheel was lost through the friction of the worm and worm wheel, which necessarily operated at very slow speeds and usually under very heavy loads. Experimental designs involving the use of spur gears and brake drum slip friction devices were tried on railway mounts and found so satisfactory as to commend themselves to further use.

222. No unusual requirements were decided upon with reference to the traversing mechanism. The ratio of one-tenth to one-twelfth of a degree per turn of the handwheel for final fine setting or for following a target, which had been found a desirable ratio on carriages previously constructed and used, was considered desirable for this carriage and may be considered at least a tentative original requirement. In the case of both the elevating and traversing mechanisms, assuming that under certain circumstances the gun would have to be elevated or the carriage traversed by hand, it was considered necessary to keep the handwheel load under 30 pounds for the proper operation of the mechanism as a whole. It has finally been decided in the case of loads for handwheels and cranks that it is better to reduce the load to such a point that the wheel may be spun very rapidly to the approximate setting rather than have such a high ratio as results in an excessive handwheel load and slow, laborious turning.

223. With reference to the carriage as a whole, perhaps no general requirements were set up except that it should be of the barbette instead of the disappearing type; and in the case of the loading mechanism no hard and fast requirements were decided upon, because it was not known just what it might be possible to develop. During the period between the design of one coast carriage and another, both the users and the designers detect possibilities for improvement, and it is usually necessary for the chief of the design section to gather together all of these suggestions to see if they can be made into a workable design. The projectile involved in this case was quite a little heavier than that used in any general service, hence the problem of handling had to be left to a rather thorough study on the part of the designers. It will be pointed out later that the decisions reached with reference to the design that has been used were arrived at by quite lengthy investigation.

DESIGN AND MANUFACTURE.

224. *Recoil mechanism—Brake.*—The elements with which the designer of the recoil mechanism could start were the weight of the gun, the weight of the projectile, the energy of recoil of the gun in terms of the travel of the projectile in the bore, and the permissible

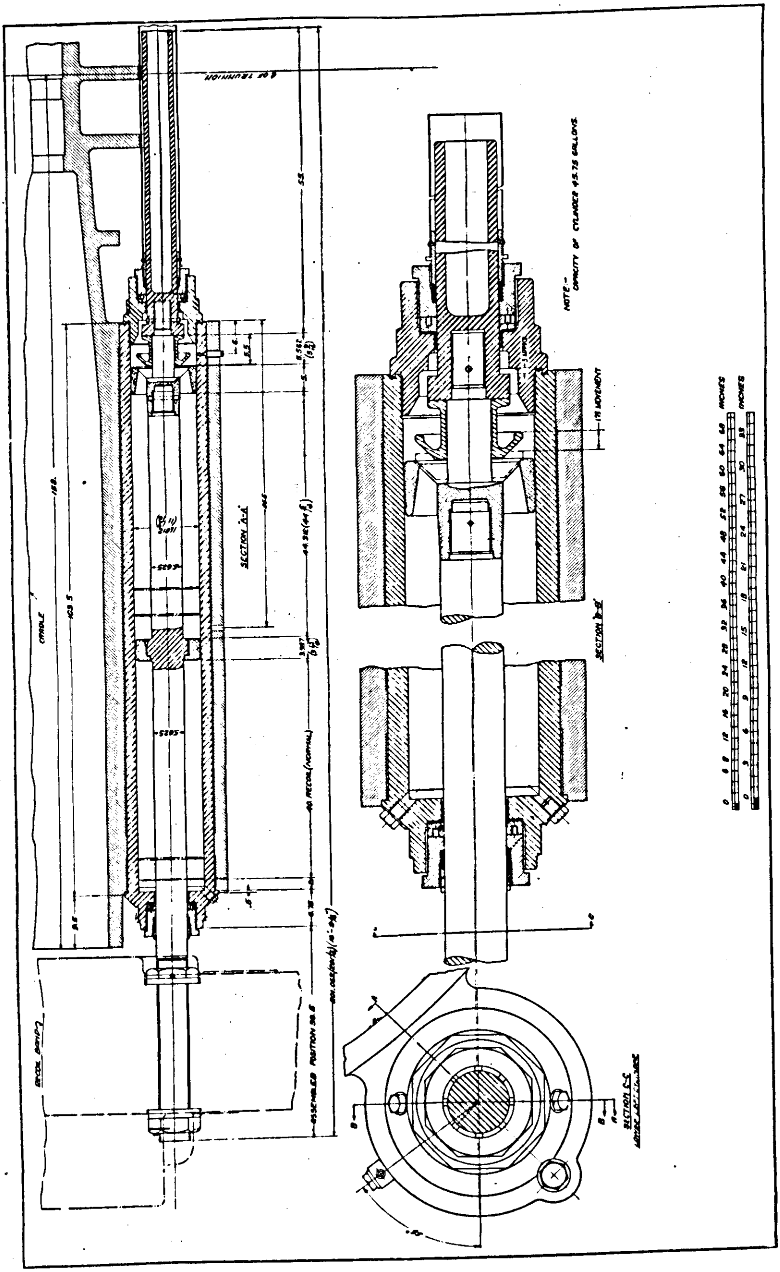
length of recoil. If no recoil mechanism is provided and the gun is mounted simply by its trunnions on the side girders of the carriage and the carriage is not free to move, the time during which the forces of recoil act is the same as the time which is required for the projectile to travel from its initial position to the muzzle of the gun. This time is less than one-fiftieth of a second, and the stresses set up in the various parts of a carriage when they are required to transmit so great an amount of energy of recoil into the foundation in so small a fraction of time are so great as to call for excessively heavy construction.

225. The excessive weight of the construction is probably the factor that prevents design on this principle. An additional objection is of course the probable disarrangement of the mechanism under such violent shocks. Field guns in use during our Civil War generally were not provided with any type of recoil mechanism. As a consequence, it was necessary to point the gun for each shot. The famous French 75-millimeter gun perfected between 1890 and 1900 is provided with a hydraulic mechanism allowing such great length of recoil as to make the stresses and the forces applied any place in the carriage at any one instant so small as to render the carriage very stable. After a few rounds have been fired to set the gun and its trail firmly in the earth, a great number of shots can be fired without further attention to the pointing of the gun either in elevation or direction. Carrying this principle to a certain limit, it means that the longer the time that is consumed in bringing the gun to a position of rest after the projectile is fired the less will be the stress in any part of the carriage, the less likelihood there is of disarrangement of the mechanism, and the lighter may be the various parts of the carriage which are especially designed to carry the firing loads.

226. After careful consideration of the effects of extreme length of recoil, it was decided that 42 inches, or 2½ calibers, would involve a base ring and racer, a recoil cylinder, and rods of such size as to be about economically balanced. A greater length of recoil than this would of course reduce the size of the recoil cylinder and rod, but would increase the diameter of the base ring. It seemed that a total recoiling weight of approximately 400,000 pounds with a predetermined energy of recoil might be stopped in a length of 42 inches without involving the use of supporting parts of excessive weight or unusual design. A normal length of recoil of 40 inches with a possibility of 2 inches excess was the final compromise.

227. The next problem in the design was a rather difficult one. There seemed to be no difficulty in designing the hydraulic cylinder, grooves, etc., so that it would bring the gun to rest at the proper

PLATE 123.



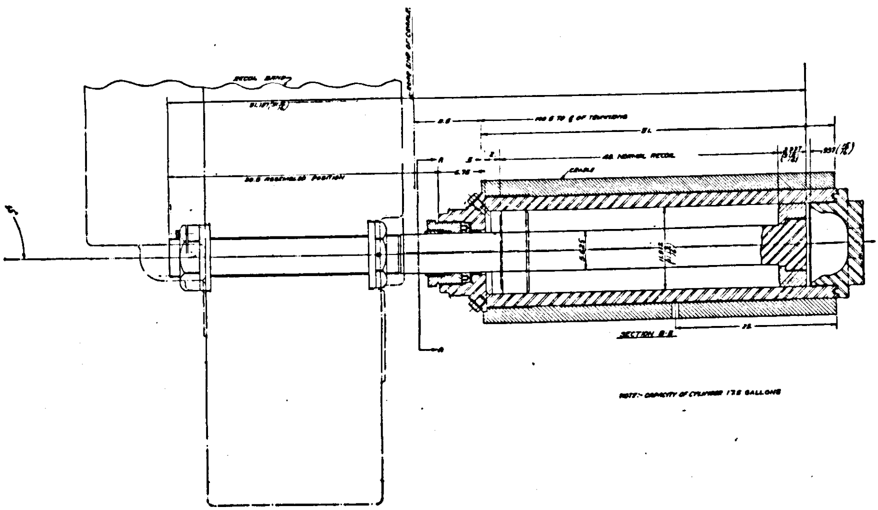
LATEST TYPE OF BUFFER FOR LARGE GUN RECOIL MECHANISM.

point and without the development of undue stresses at any time during the recoil; but the unusual requirements of extreme limits of elevation of minus 7 degrees and plus 65 degrees had been given, and no recoil mechanism of the usual design as to buffer had ever been so perfected as to seem satisfactory for these extremes. In fact, tests of existing recoil mechanisms at extremes of zero and 45 degrees had shown rather clearly that the usual type of buffer, Plate 235, is not satisfactory. The fault is that when the buffer is so designed as to function satisfactorily at zero, the gun will not return to battery at higher elevations, and when designed to return the gun to battery properly at 45 degrees it does not function properly at lower elevations, in some cases permitting the gun to charge back in battery so violently as to endanger the mechanism. This problem had been recognized for some time, and it is probable that the solution arrived at, which is certainly a most admirable one, is the result of several years' study and research. It will be observed in Plate 123 that two of the recoil cylinders are made of double length, and the rod contains two pistons, as shown in the upper view. The cylinder from the forward end to the solid piston is of the usual design. The extension of the rod and the second piston are the features of unusual design. This new type of buffer is shown in clearer detail in the lower view. It is seen here that the buffer comprises a piston in conjunction with what might be termed a floating valve. As the gun recoils the oil flows freely through the openings in this piston with the valve as far away from the piston as it can move. As soon as the recuperator begins to return the gun to battery this floating valve is forced back against the buffer piston and the oil permitted to flow through certain openings at such a rate as to bring the gun to rest without any severe shock. This mechanism has been found to function as satisfactorily at the lowest elevation, minus 7 degrees, as at the highest, plus 65 degrees. It was decided to use two hydraulic brake cylinders of the design, Plate 124, and two others of double length, including buffers, as shown on Plate 123.

228. *Recuperator.*—The pneumatic recuperator used in this carriage, Plate 125, is a modification of an identical design used on a number of railway carriages. It is simply modified in size, dimensions, etc., to adapt it to this carriage and to the returning to battery of a weight of 400,000 pounds at an elevation of 65 degrees. The total number of recuperators of this type decided upon was two, it being impracticable to provide the carriage with a single recuperator of such size as to return the very great recoiling weight to battery at the maximum elevation. In arranging these recoil and recuperator mechanisms about the gun it was thought best to arrange them symmetrically—that is, to arrange the two simple hy-

draulic brakes opposite each other with one at the upper left and the other the lower right, Plate 126, the double-length recoil cylinders at the upper right and lower left, and the recuperators directly above and below the gun. The advantages of this symmetrical distribution of cylinders about the center of the gun on a carriage of the type under discussion are twofold. The question of locating the center of gravity of the recoiling parts as well as the tipping parts on, or close to, the center of bore is of primary importance and is greatly simplified by the above arrangement of cylinders. When the gun recoils, the pull exerted on the various rods in the cylinders is transmitted, by means of the cradle and trunnions, to the side frames. When these rods are symmetrically located about the bore, which is in the plane of the trunnions, of course this pull is balanced and

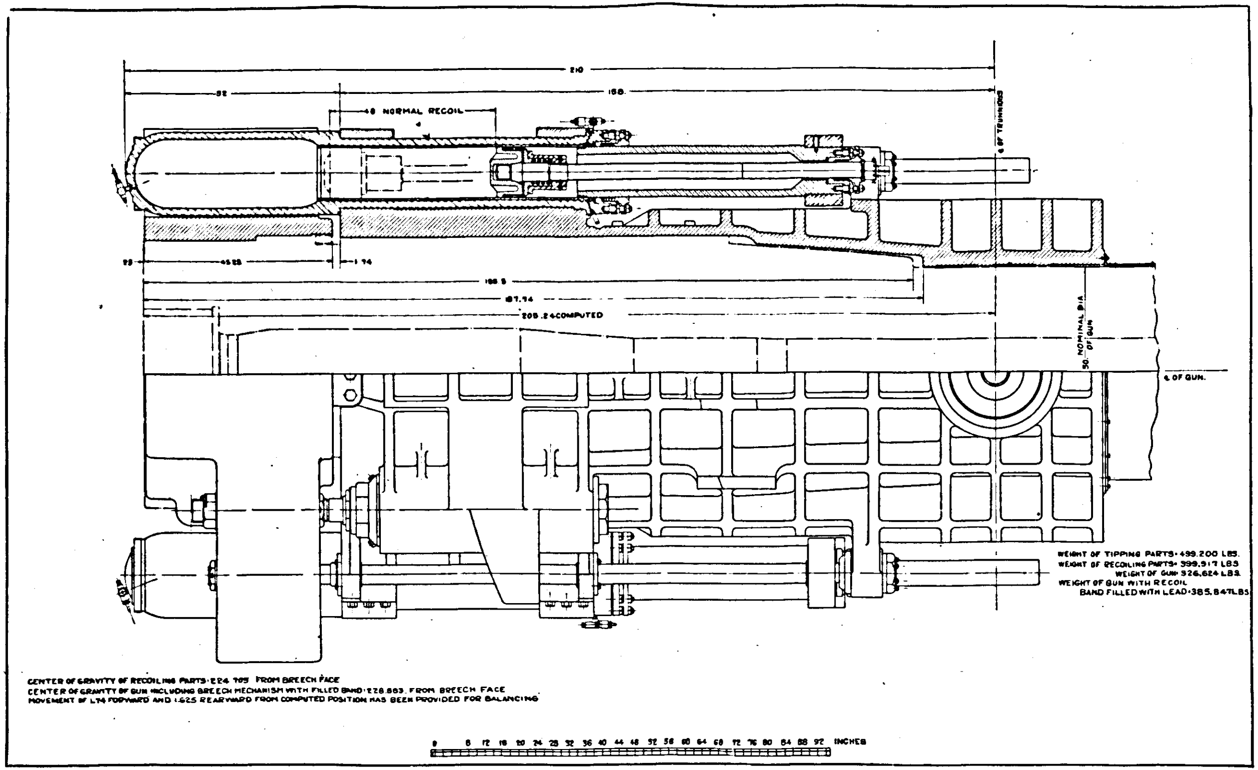
PLATE 124.



LATEST TYPE OF RECOIL BRAKE WITHOUT THE VALVE BUFFER.

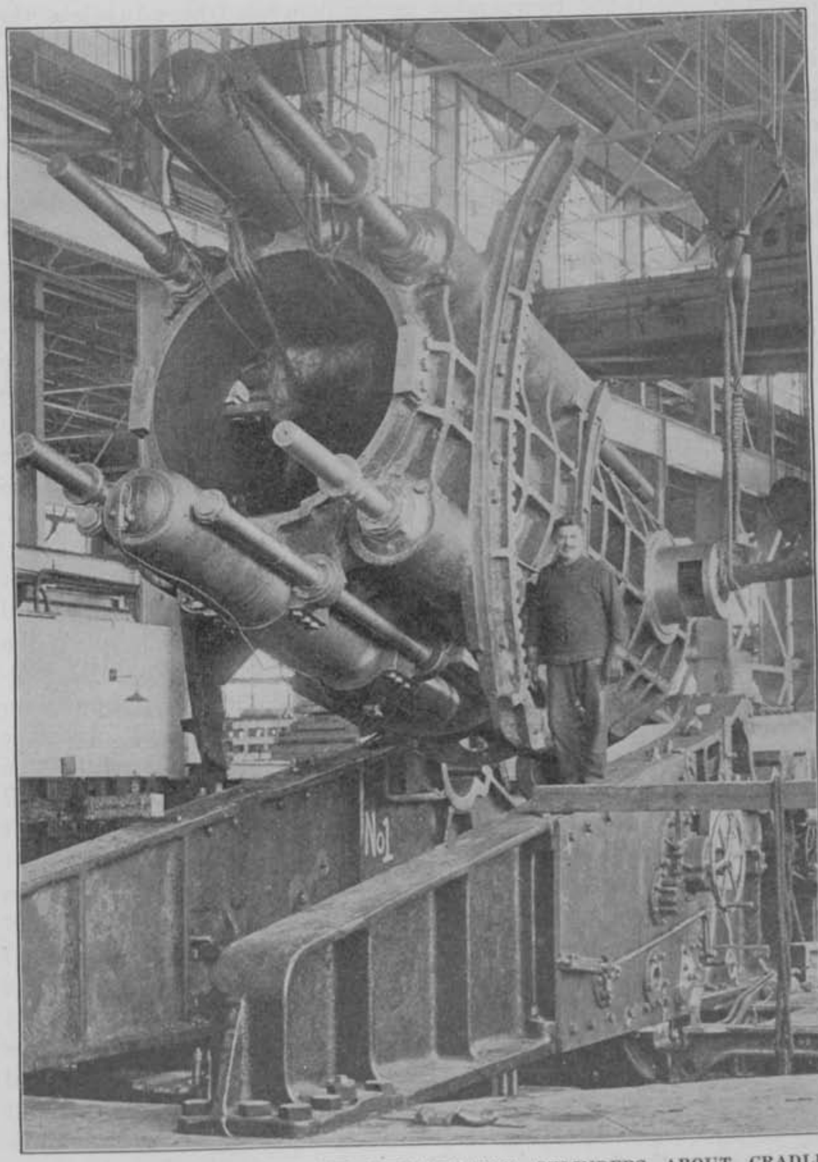
there is no tendency for the gun to "whip." The fact that the vertical, as well as the horizontal, center of gravity of the tipping parts is in the plane of the trunnions will maintain the balanced condition of these parts at all angles of elevation. During the late war the Germans made use of a great number of naval carriages on their coast defense and railway mounts and in many cases found it necessary to resort to counterweights on top of the cradle to compensate for the unbalanced condition of the tipping parts due to the assembling of the cylinders underneath. These carriages were designed for use in turrets where the lowness of the roof necessitated the placing of the cylinders below the gun and as the angle of elevation rarely exceeded 15 degrees the unbalanced condition which becomes serious at the higher angles was not encountered to any great extent. It is logical

PLATE 125.



PNEUMATIC RECUPERATOR WITH LIQUID-SEALED PACKING.

PLATE 126.



ARRANGEMENT OF RECOIL AND RECUPERATOR CYLINDERS ABOUT CRADLE. LOWERING ASSEMBLED CRADLE ONTO SIDE FRAMES.

to assume that a carriage which equalizes its firing forces, as described above, is an improvement in design, from the point of shock reduction in all its parts, over carriages of the other types.

229. In brief, the recuperator mechanism used here involves the use of a floating piston, the rod of which passes through the forward end of the main piston, and the space between the floating piston and the main piston is filled with oil. The initial pressure of the air in this recuperator is approximately 2,000 pounds per square inch, and the tendency of this pressure is of course, first, to force the floating piston forward. This in turn has a tendency to eject the oil, but failing to do this, transmits through the hollow piston, yoke, and connecting rods to the rear of the gun the necessary pull to retain the gun in battery. As the oil slowly leaks out the floating piston is forced forward, and the distance to which the indicator on the forward end of the floating piston projects is an indication of the extent of loss of oil and the exact position of the piston in the cylinder. A special oil pump is provided to force in more oil from time to time, and after the air pressure has once been placed at a certain point there is no particular reason why the air should escape, since it can not escape except through leaks in the wall of the air cylinder.

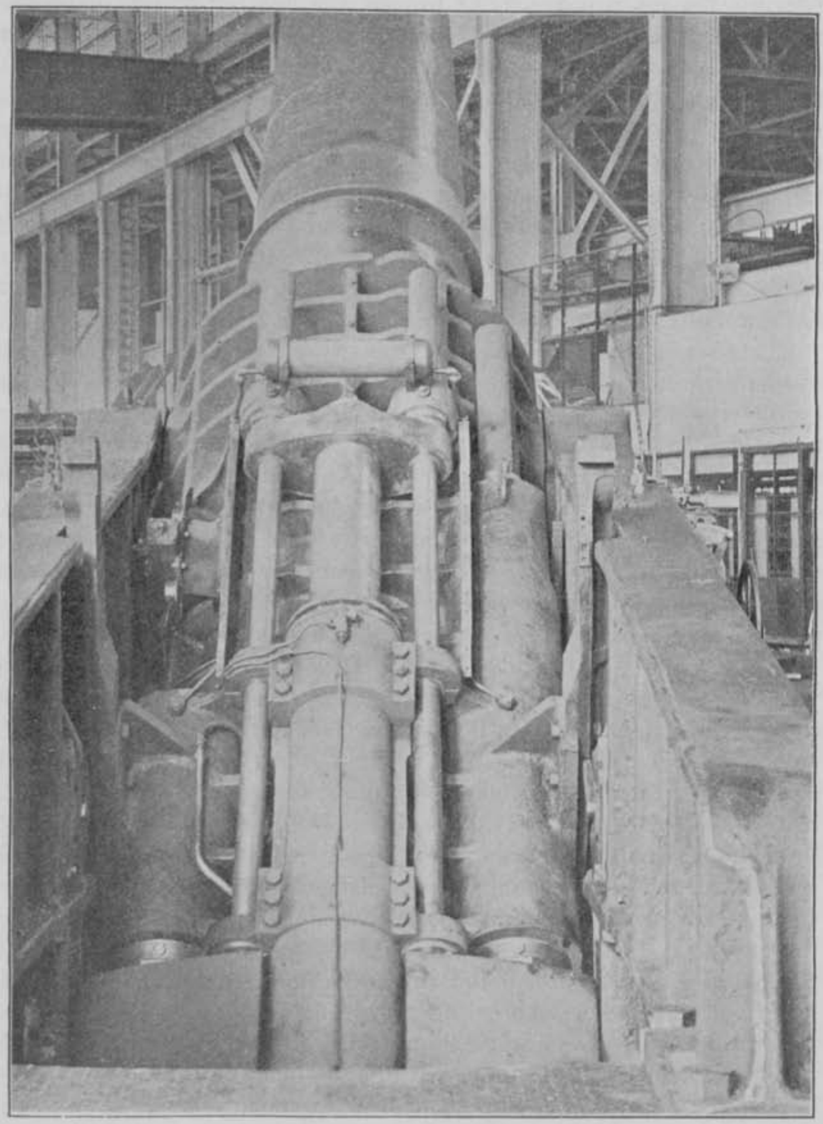
230. *Manufacture.*—Past experience has shown that it is not satisfactory to machine the recoil cylinders directly in the cast-steel cradle. In spite of all precautions and attempts to produce the finest of castings, the material of the cradle is found to be sufficiently porous to permit the escape of the oil through the pores on the building up of the tremendous pressure under recoil. In some cases various compounds were used in the attempt to fill these pores, and sometimes they have been successful. It has seemed better, however, in recent designs to simply provide a sleeve on the cradle into which a forged cylinder may be fastened, which of course shows no signs of porosity. The designs shown in Plates 123 and 124 then involved first the casting of ingots of the proper size to forge into rough cylinders that could be turned and bored to the final cylinder shown assembled in place in the cradle. The short cylinder is closed at one end by means of a plug and has a stuffing box at the other through which the piston rod passes to the recoil band of the gun. A bronze bushing is provided on the end of this rod to serve as the piston, thereby meeting the requirement that the piston and cylinder be of different metals. The buffer pistons used in the long cylinder shown above are likewise of bronze, while the floating valve is of forged steel. In the upper cylinder it is seen likewise that stuffing boxes are provided at both ends and that the end of the piston rod has an extension passing out through a tube-shaped shield or guard toward the muzzle of the gun. There

is nothing sufficiently unusual about the manufacture of these parts to warrant detailed discussion.

231. The recuperator, Plate 125, is in six parts; three of these are not shown in this plate. The air cylinder or bottle is a machined forging, the main piston is of bronze, the floating piston of bronze and provided with special **U** leathers, the floating piston rod of steel, the yoke of cast steel, and the connecting rods of steel. As one views the cradle in Plate 125, the muzzle of the gun is to the right and the recoil band to the left. It is necessary then of course to connect the forward end of the main piston to the recoil band of the gun by means of two connecting rods. The top of the recuperator, the main piston, the yoke, and the two connecting rods are shown best, perhaps, in Plate 127. Their connecting with the recoil band by means of the two nuts on either side of the recuperator is shown in Plate 140.

232. *Cradle—Design.*—Since the various elements of the recoil mechanism have been designed, it is now possible to pass to the cradle which is to carry a gun of a certain diameter and weight, is to receive in lugs or sleeves about its circumference six recoil and recuperator cylinders, is to carry two elevating racks providing for elevation between minus 7 degrees and plus 65 degrees, and must support the whole and transmit the energy of recoil by means of two trunnions resting in the usual bronze bearings, and be provided with such antifriction mechanisms as will enable the gun to be elevated and depressed each within 30 seconds by man power on a handwheel with a maximum handwheel load of 30 pounds if handwheel operation is necessary. The cradle, as finally designed to meet all of these requirements, is shown in Plate 125, part of which is in section and part full outline. It will be observed that the surface is of the gridiron design, and here again it may be well to mention differences in design that have been discussed for a number of years. Questions have been raised as to whether it is desirable to so construct cradles of the gridiron design as to render them particularly rigid, or whether they need be designed for strength only, disregarding the matter of rigidity. Practically all of the cradles of the great seacoast guns found in the German fortifications in Belgium were of the smooth-cylinder type. Apparently they have not felt the need of the rigidity that we have thought desirable. This is a point which is difficult to settle, and since the carriage involved here is of such unusual importance, it was thought best not to take any chances, and the gridiron design was used. It had already been decided that the six recoil and recuperator cylinders should be distributed in such a way as to balance each other, hence the placing of three above the center and three below so placed as to be ar-

PLATE 127.



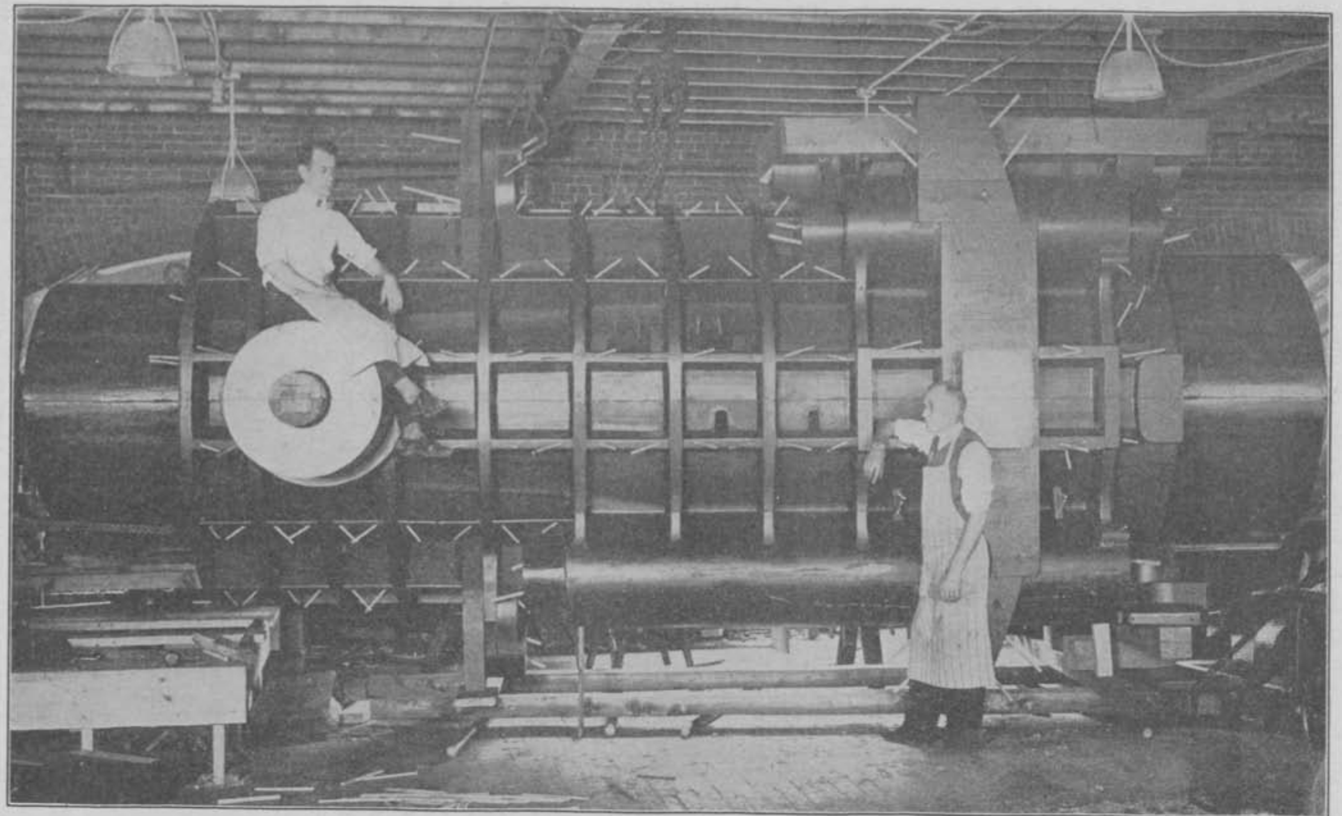
TOP OF CRADLE SHOWING LONG AND SHORT RECOIL CYLINDERS AND RECUPERATOR UNIT.

ranged in pairs with those above. The diameter of the trunnions was made such as to be sufficiently strong to withstand the shearing stress at the moment of transmission of maximum energy into the side frames of the carriage. This implies, of course, the provision of a proper factor of safety. The trunnions are so placed likewise as to permit the total combination of tipping parts to be so balanced with the gun in battery as to provide a muzzle preponderance of a certain amount when the gun is empty and a breech preponderance of an approximately equal effective amount when the gun is loaded.

233. Each sleeve provided for the reception of a recoil or recuperator mechanism was designed of sufficient strength to take the maximum pull that would come upon it, and the cradle was made of sufficient rigidity to transmit the total pull into the trunnions without so warping as to pinch the gun at any time in its recoil. Cast steel No. 2, with a tensile strength of 75,000, was specified as desirable for this part of the mechanism. The pattern made for the casting of this cradle is shown on Plate 128. The operations of finishing of the cylinder involved the boring of the inside as well as each of the sleeves for the recoil and recuperator cylinders, the turning of the trunnions, and the machining of the various seats, pads, etc., for the attaching of the elevating racks, rods, etc. The total weight of this steel casting is approximately 102,000 pounds. The finishing, Plate 129, involves likewise the machining of two keyways, one at the top and one at the bottom of the inside, to provide for the two bronze splines attached to the top and bottom of the gun, to prevent rotation of the gun. Plate 130 shows a dummy cradle provided for the setting of the keys on the gun in proper alinement with the holes in the recoil band.

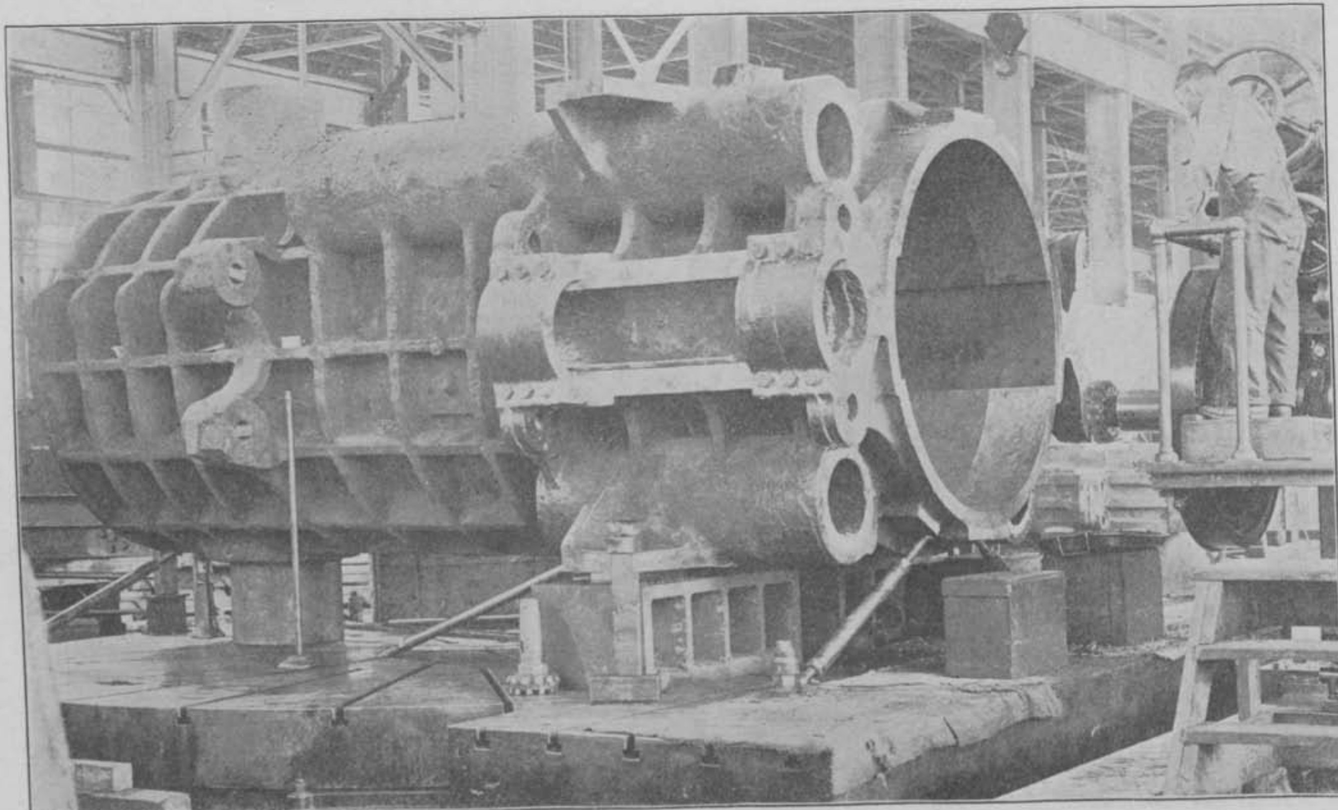
234. *Recoil band.*—In determining the length of recoil permissible in this gun, one of the factors that was considered was the use of a counterweight on the breech of the gun that would permit the mounting of the gun in the cradle with the breech as close as possible to the trunnions. The decision as to the size and weight of this counterweight involves a consideration of the total weight of the tipping parts in the bearings as against the desired length of recoil in terms of stresses involved and diameter of the base ring. The decision that was finally reached with reference to the weight of the recoil band which serves at the same time, as a counterweight is of course an arbitrary one. In this case the weight of the band is 99,000 pounds, and its addition to the weight of the cradle and gun does not raise the total weight to such a point as to require excessive reduction in elevating gear ratio to bring the handwheel load within proper limits. This counterweight is shown in process of being bored to fit

PLATE 128.



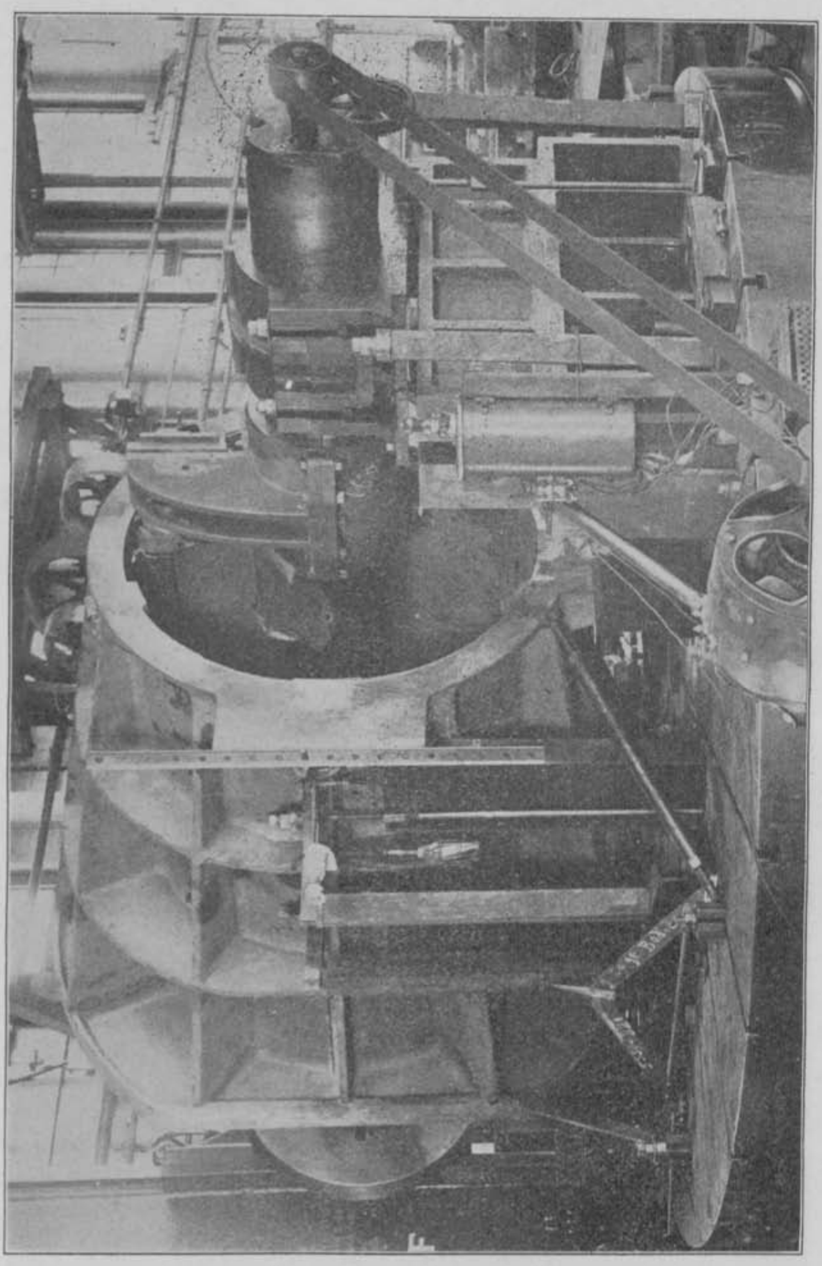
PATTERN FOR THE CRADLE OF THE 16-INCH 50-CALIBER GUN CARRIAGE.

PLATE 129.



MACHINING THE ARMS OF THE RECUPERATOR RECESS OF 16-INCH GUN CRADLE.

PLATE 130.

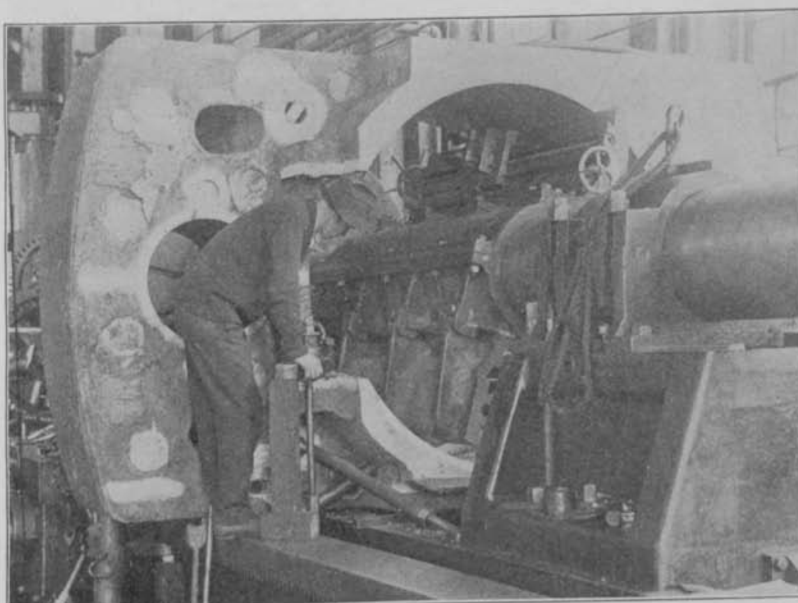


FIXTURE OR DUMMY CRADLE FOR SETTING THE SPLINES OR KEYS ON THE GUN.

over the breech of the gun in Plate 131. It is shown marked off likewise for the recoil and recuperator rods. The large hole to the left is provided for the rear end of the bottom recuperator cylinder. This counterweight assembled to the gun is shown in Plate 132 and on the gun as finally assembled and being tested in Plates 133 and 134. It is made of cast steel No. 2 and a portion of it is hollow and is filled with lead to permit the increasing of its weight without the increase of its size.

235. *Elevating mechanism.*—The requirements under which the designers of the elevating mechanism worked comprised a weight of tipping parts of 500,000 pounds, a range of elevation from minus

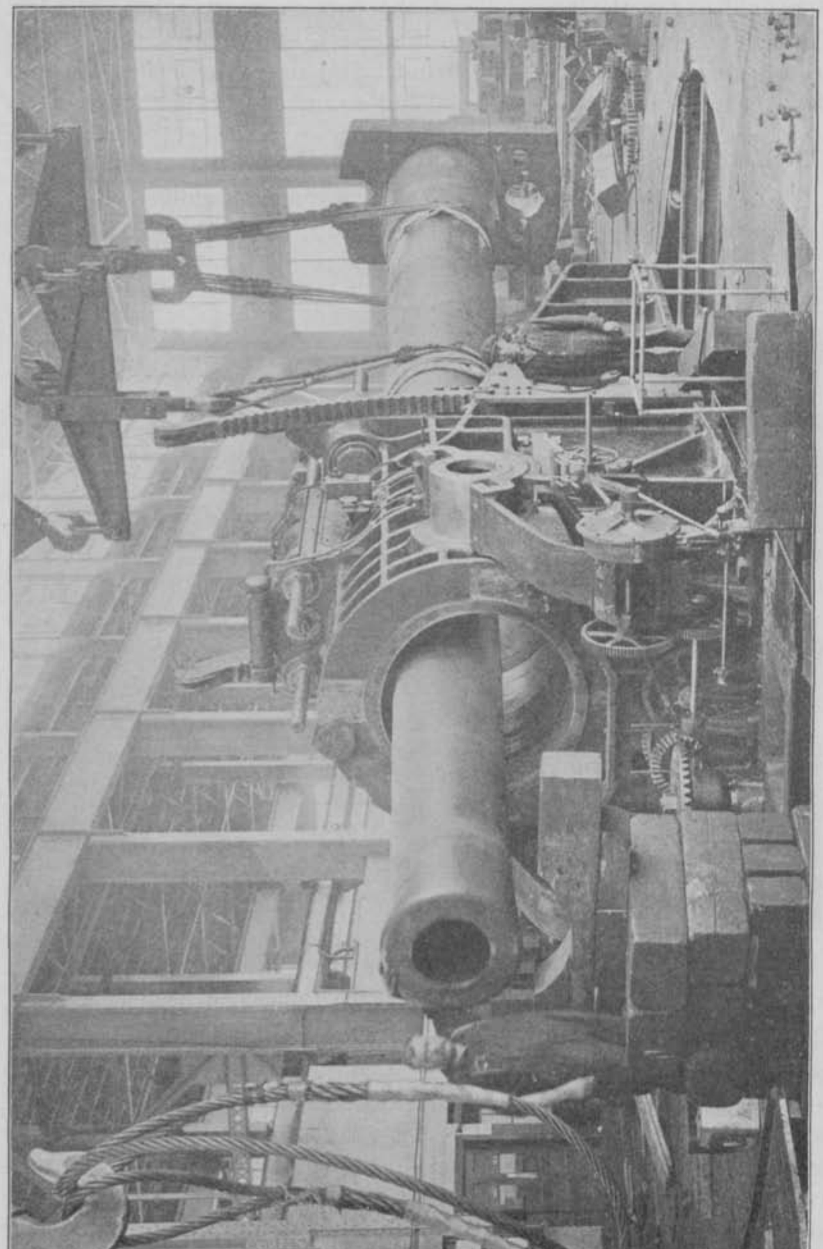
PLATE 131.



BORING THE GUN HOLE IN THE RECOIL BAND.

7 degrees to plus 65 degrees, the specification that the mechanism should not include worms and worm wheels, and the further specification that the ratio of the gearing should be approximately one turn of the handwheel to 1 degree of elevation with a maximum handwheel load of 30 pounds. Operating under these specifications the mechanism was designed as shown on Plates 135–140. This comprises two spur gear circular racks attached one to each side of the cradle and with a pitch diameter of 240 inches, the center of the gear being the center of the trunnion. A series of spur gears lead from this rack to the handwheel on the side of the carriage and through the Waterbury speed gear to an electric motor. A brake drum is pro-

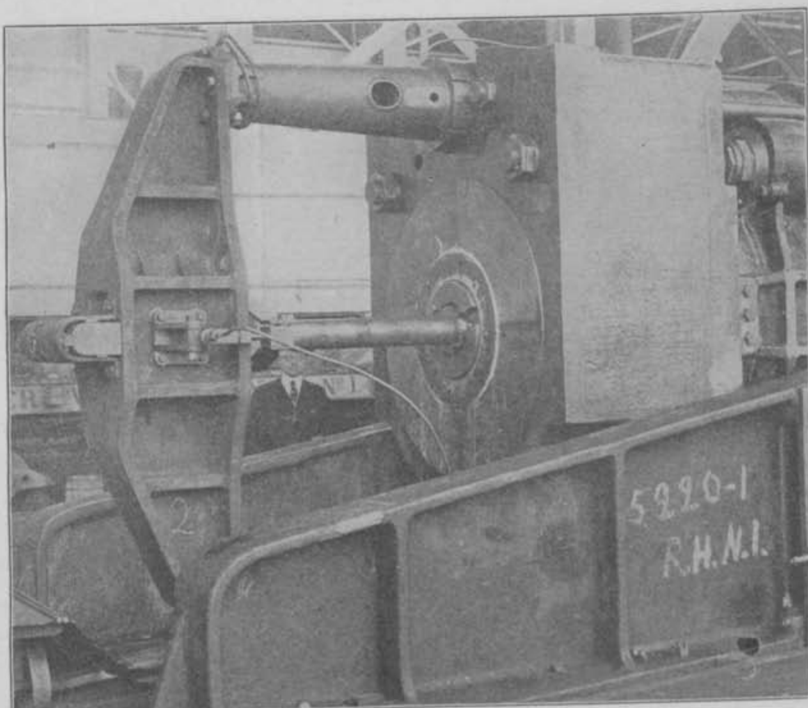
PLATE 132.



MOUNTING THE GUN AND RECOIL BAND IN THE ASSEMBLED CARRIAGE.

vided on one of the gears as shown in Plate 136, in such a way that on release of the brake band by means of the lever shown the muzzle or breech preponderance of the gun is free to drive the motor and slowly elevate or depress it as the case may be. On firing of the gun this slip friction device likewise permits the slight slip of the mechanism without undue strain in the gearing. An antifriction device, Plate 137, involves a series of rollers carried in a cage and a heavy collar. This collar is supported on the beam, the end of which is in turn supported on three sets of Belleville

PLATE 133.

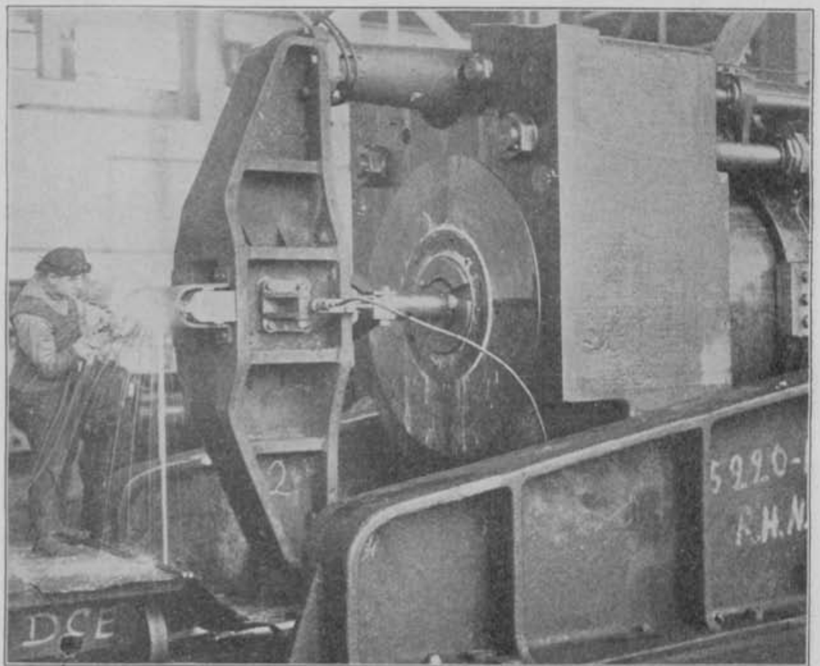


SPECIAL COUNTER-RECOIL TESTING DEVICE; GUN SHOWN IN BATTERY POSITION.

springs. Adjustment of the rod from the springs raises or lowers the end of the beam, thereby raising the trunnions until the main section of the trunnion is approximately 0.02 of an inch off the main bearing. When the supporting beams are so adjusted the gun is being carried in a roller bearing. When the gun is fired, however, the Belleville springs are compressed just sufficiently to permit the trunnion to come in contact with the main bearings and the energy of recoil is transmitted through the heavy side frames without injury to the roller bearings.

236. *Manufacture.*—The processes involved in the manufacture of the various parts of this mechanism are not sufficiently unusual to warrant much discussion. In Plate 141 the procedure in machining the gears on the elevating racks is shown. It was not possible to predict before a trial just how efficiently this mechanism would function. On completion it was found that the load on the handwheel, instead of reaching the maximum of 30 pounds considered permissible, did not exceed 17 pounds. The time required to elevate the gun from zero to 65 degrees did not exceed 27 seconds. The rollers

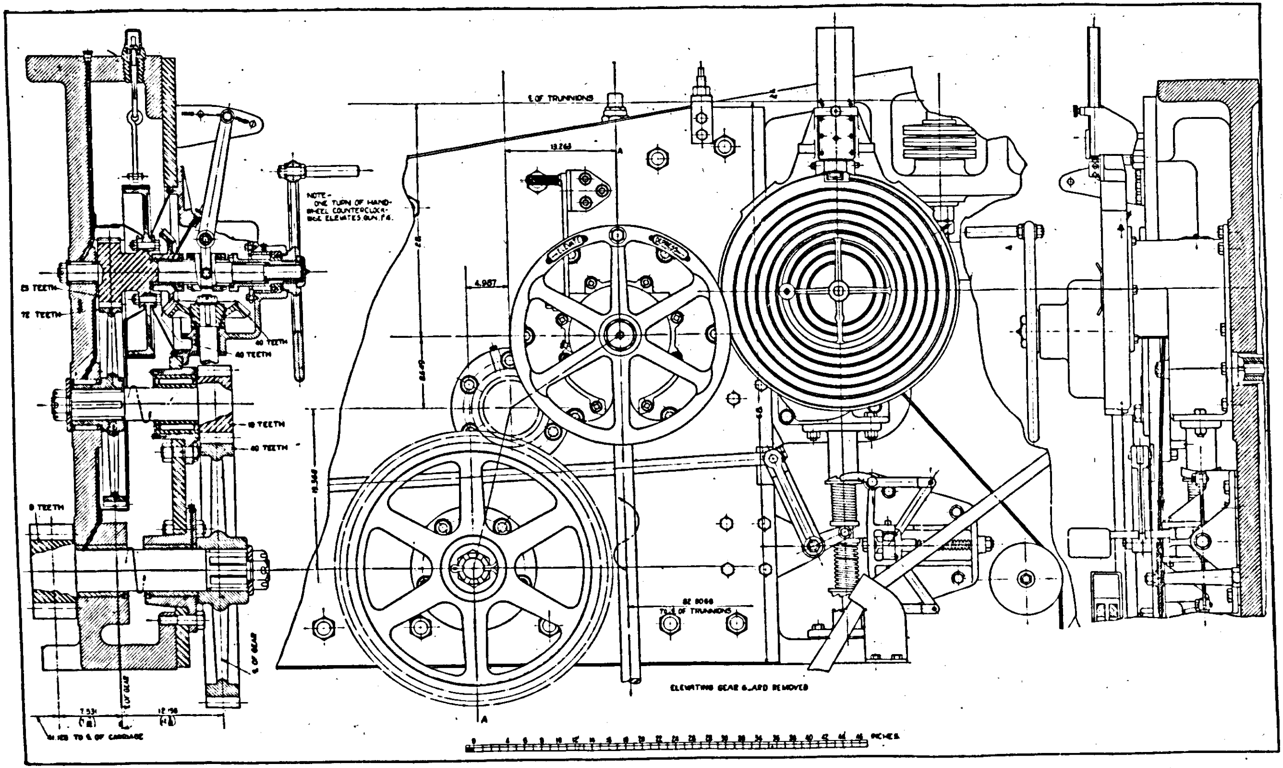
PLATE 134.



COUNTER-RECOIL TESTING DEVICE. GUN ABOUT TO BE RELEASED FROM THE FULL RECOIL POSITION.

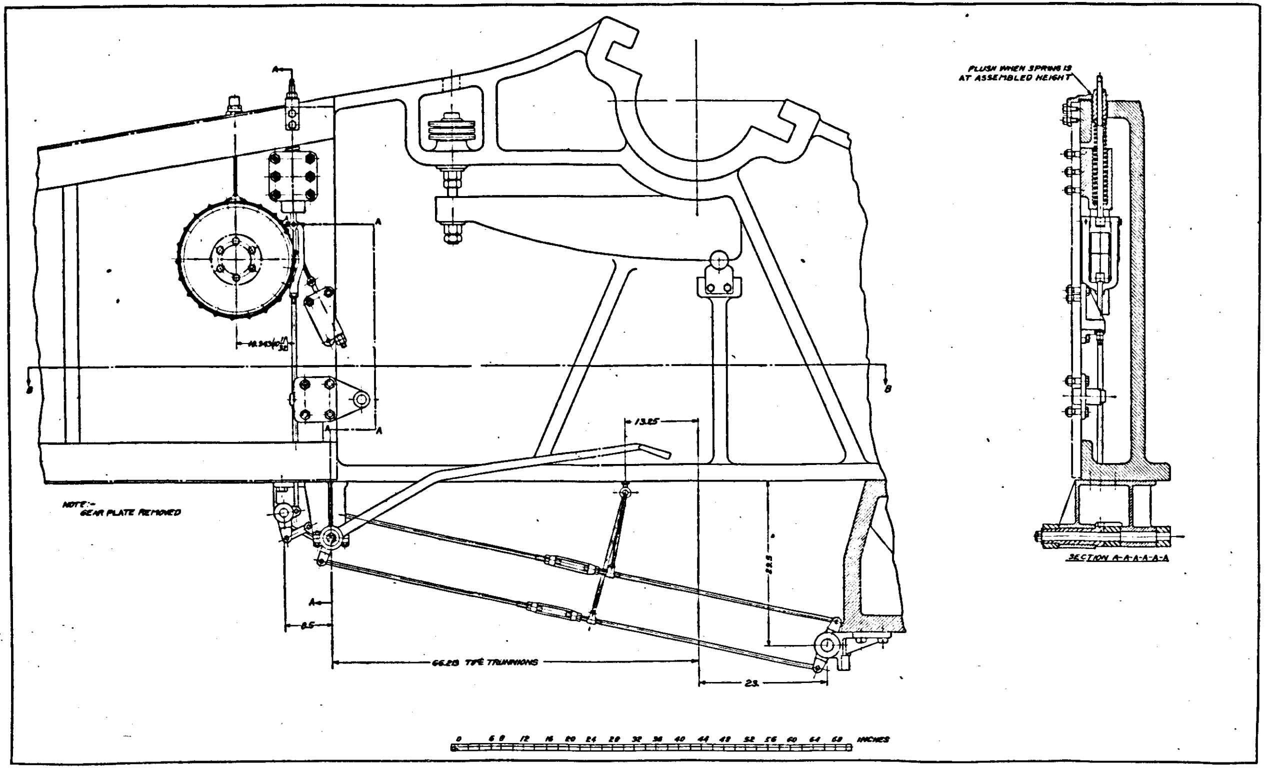
of the trunnion roller bearing were hardened to a scleroscope hardness of 100. The inner and outer sleeves have a hardness of 96 and 100. In testing the roller bearings a load of 800,000 pounds was applied, and even with this extreme load, which is twice the weight of the tipping parts, it was found possible to rotate a journal inside of the roller bearing with relative ease. A Waterbury speed gear is incorporated in the mechanism and through it the gun is elevated and depressed by means of an electric motor, the speed gear making it possible to elevate it at a maximum speed practically to the desired point and then reduce to the point of final setting. An

PLATE 135.



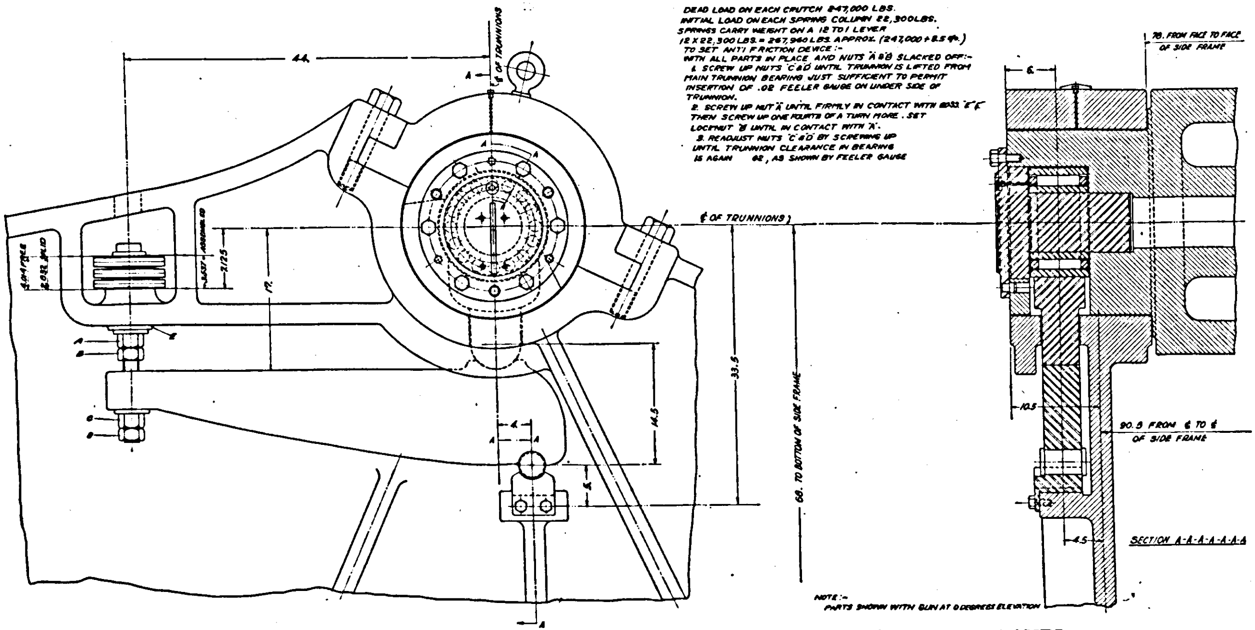
ELEVATING MECHANISM ASSEMBLY, RIGHT SIDE OF CARRIAGE.

PLATE 136.



ASSEMBLY OF BRAKING DEVICE FOR ELEVATING MECHANISM.

PLATE 137.

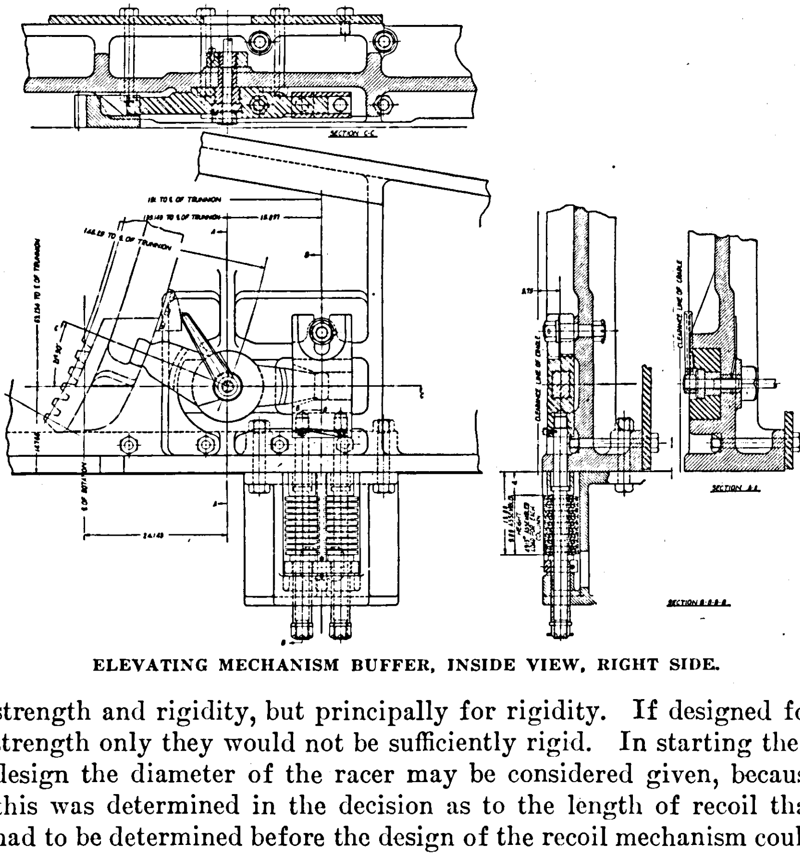


DEVICE FOR REDUCING FRICTION BETWEEN CRADLE TRUNNIONS AND SIDE FRAMES.

indicating mechanism, Plate 135, is likewise added for the purpose of showing without the use of a gunner's quadrant the elevations, and the mechanism has been so arranged as to permit the gun to be elevated through its breech preponderance when loaded to within 1° of the desired elevation. This final degree is secured either through the operation of the handwheel or through power from the electric motor.

237. *Chassis.*—The chassis includes the two cast-steel girders on which the cradle is directly supported by means of its trunnions and the four-piece racer. These side frames are designed for both

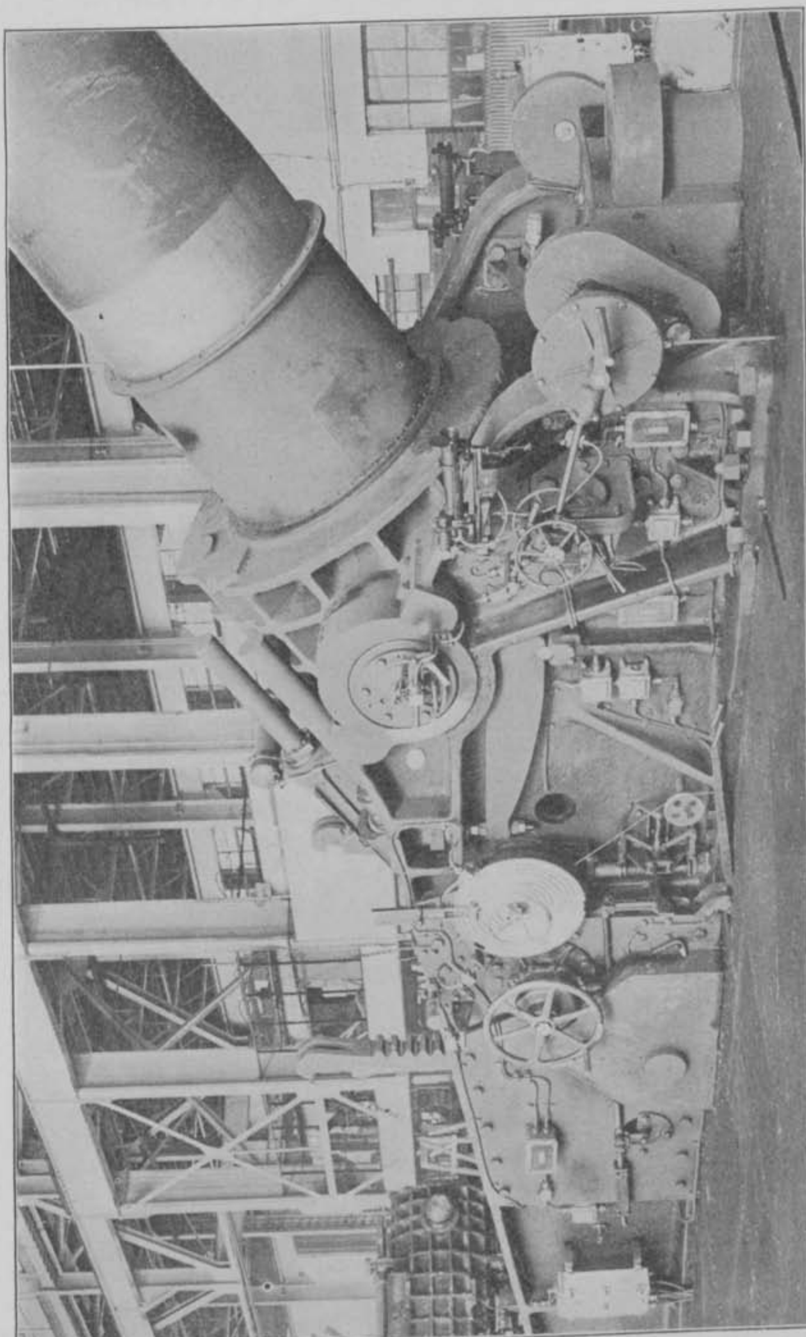
PLATE 138.



ELEVATING MECHANISM BUFFER, INSIDE VIEW, RIGHT SIDE.

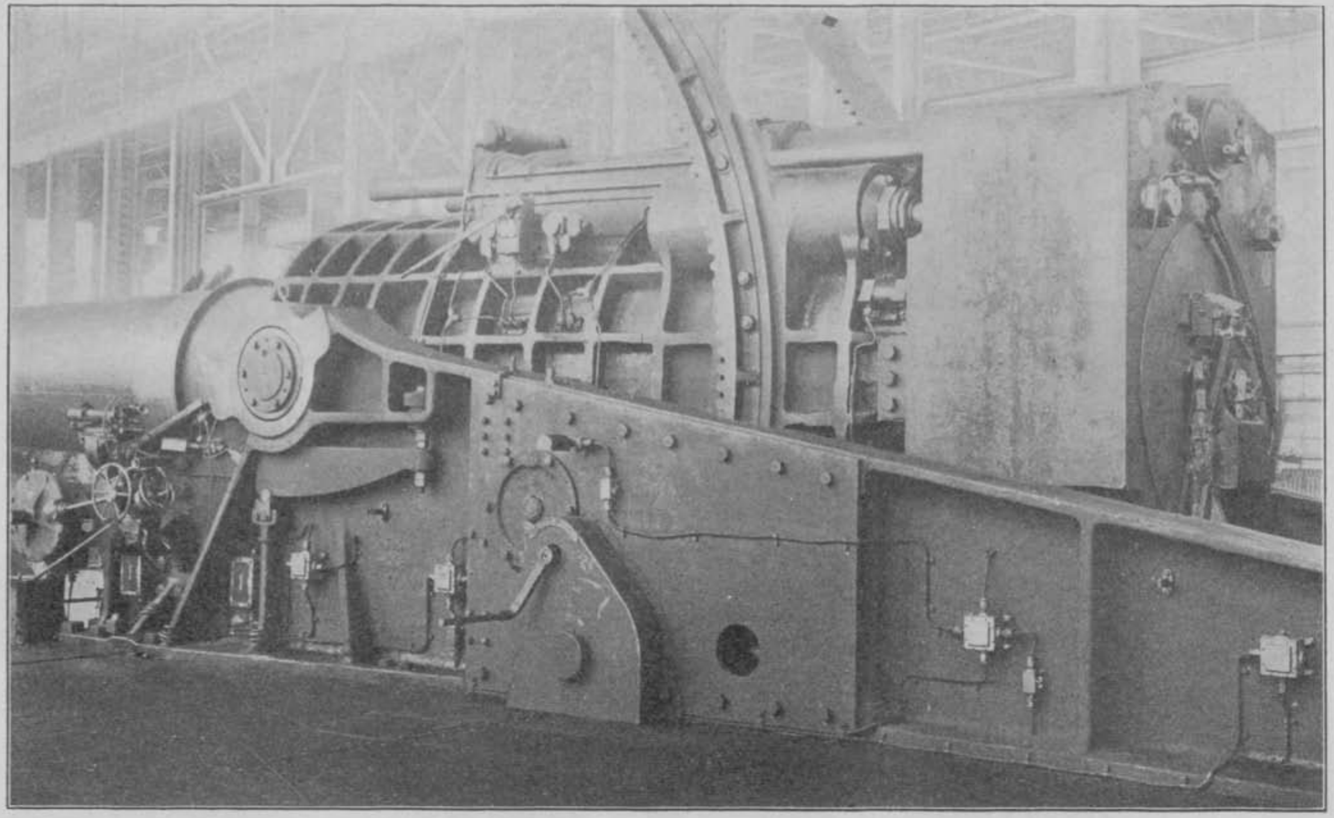
strength and rigidity, but principally for rigidity. If designed for strength only they would not be sufficiently rigid. In starting their design the diameter of the racer may be considered given, because this was determined in the decision as to the length of recoil that had to be determined before the design of the recoil mechanism could be undertaken. The distance of the center of the trunnions above the racer was likewise a predetermined dimension, hence the designer was simply confronted with the problem of designing the beams or girders of a certain length and supporting a certain maximum load at a certain point in their length and at a certain distance above their base. Numerous lugs and pads were provided of course in

PLATE 139.



RIGHT SIDE OF ASSEMBLED CARRIAGE.

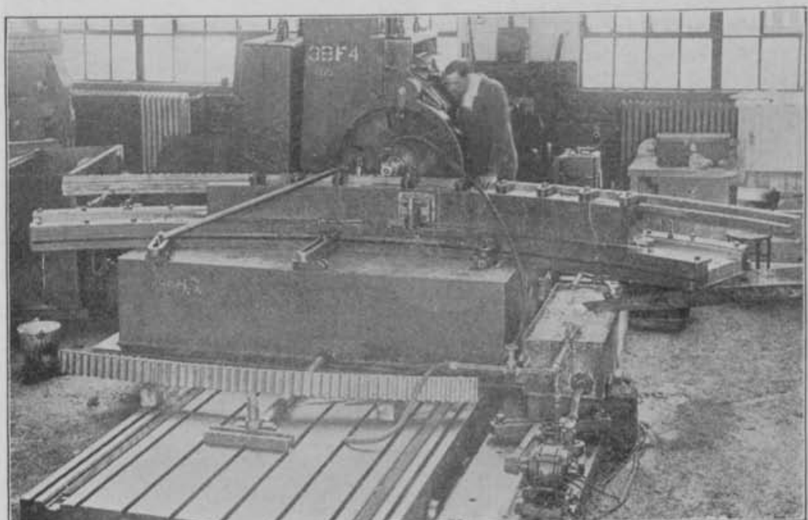
PLATE 140.



LEFT SIDE REAR OF ASSEMBLED CARRIAGE.

various places for the reception of the various mechanisms that would be attached to these beams, but these are minor problems in the design. As finally designed, the beams with their web of a certain thickness and ribs of certain thickness and at various points in their length represent more or less an arbitrary design. The beam is first designed for strength and then the necessary ribs added for rigidity and to an extent found satisfactory by observation of previous designs. It is difficult to prove to what extent ribs are necessary except by observing failures of similar beams. It is the usual practice to play safe in the providing of metal for the purpose of rigidity up to a point where additional weight would seem excessive.

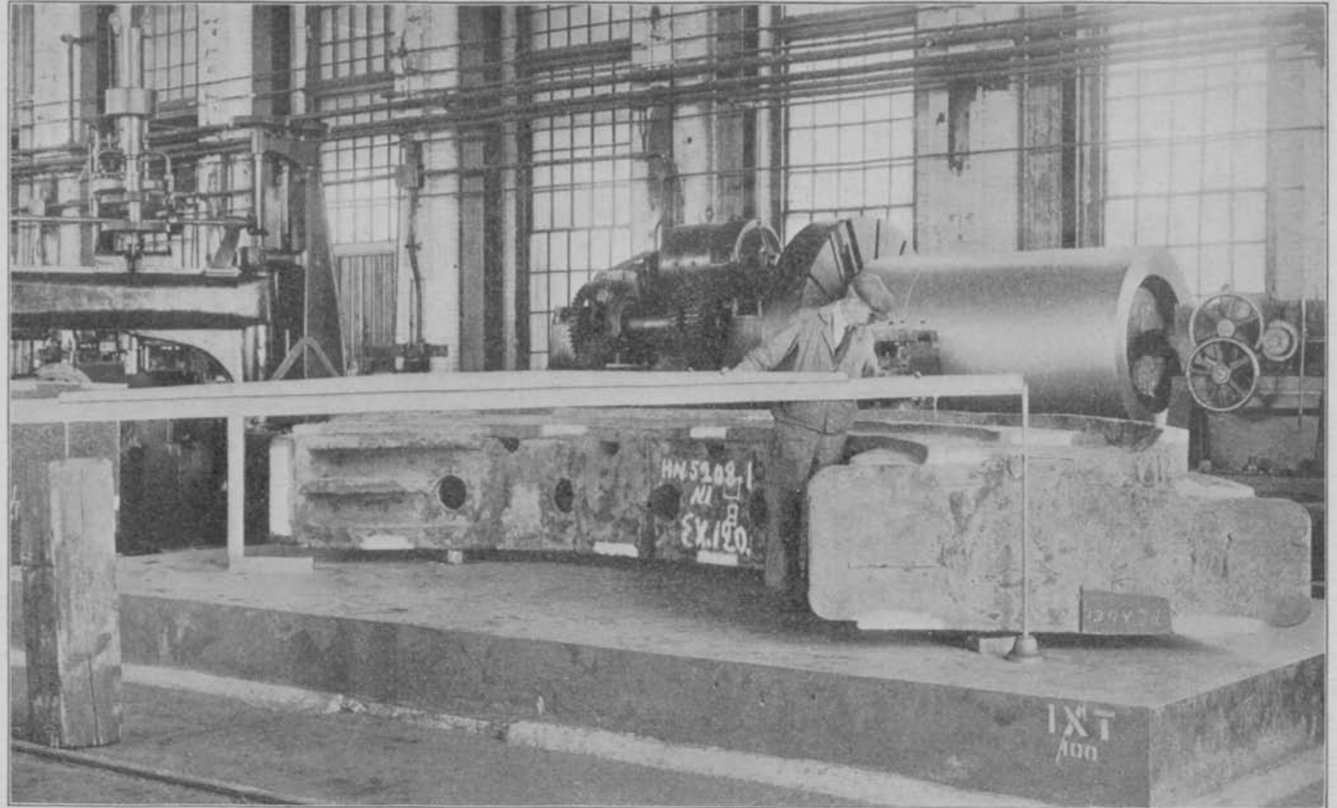
PLATE 141.



MACHINING SECTIONS OF TRAVERSING RACK.

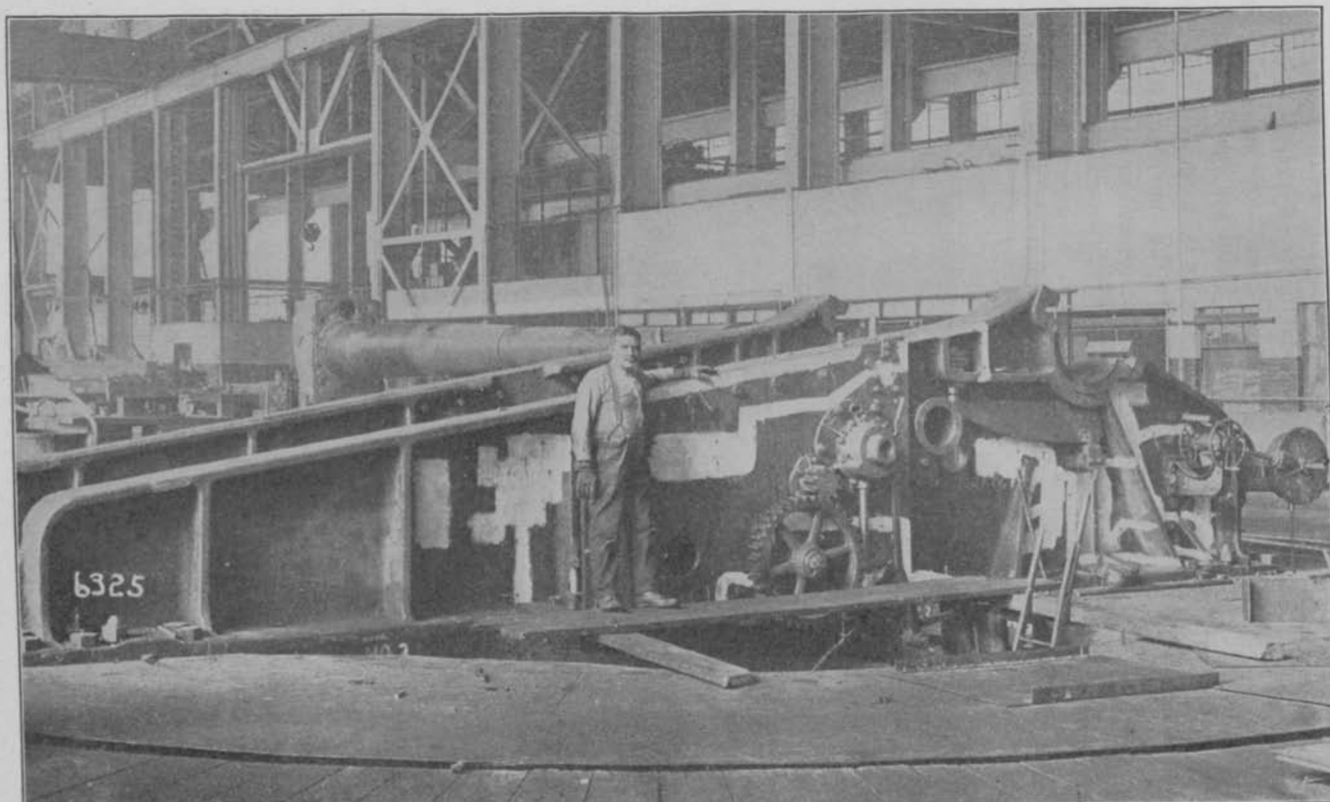
238. The racer is of such a diameter as to make its manufacture by casting in one part very difficult, hence the decision to subdivide it into four quarters. The problems involved in the design here are the providing of a ring sufficiently rigid that when two beams such as those already designed are supported on it at their ends only, it will bear evenly on all of the traversing rollers and not be distorted under the stress of firing. Here again there is relatively little precedent and it becomes necessary finally to decide upon the size of sections and thickness of webs and ribs somewhat arbitrarily. No failures have been observed in other rings of this size and under similar conditions, hence we do not know definitely just how much one may reduce in the size of sections, thickness of ribs, etc., and still remain within a satisfactorily safe limit. The

PLATE 142.



LAYING OFF FOR MACHINING ON QUARTER SECTION OF RACER CASTING.

PLATE 143.

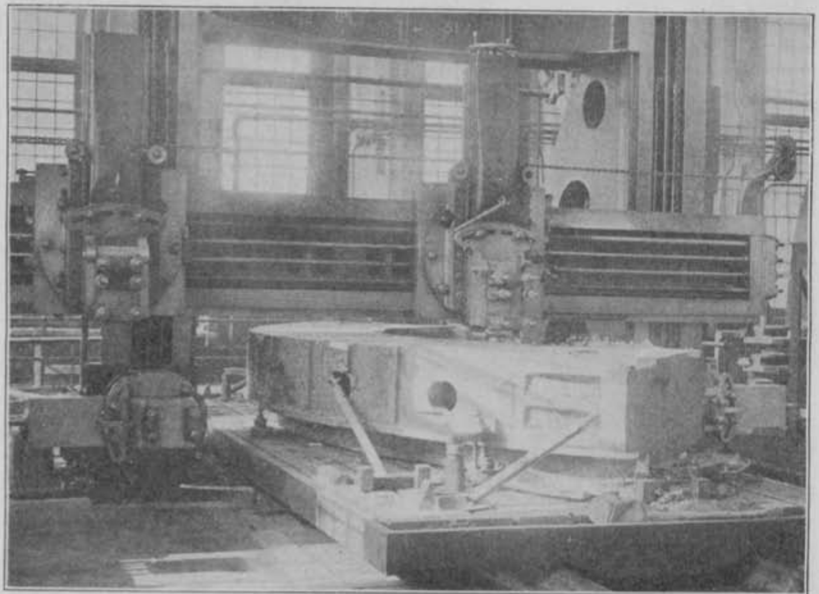


ASSEMBLING THE ELEVATING GEARING ON THE SIDE FRAMES.

final design of a quarter section of the racer is shown in Plate 142. It is relatively a box section in that it is cast hollow; the under surface is intended to serve as the upper bearing for the circle of cones.

239. *Manufacture.*—The side girders or beams are made of cast steel No. 2 and are machined, as shown in Plate 143, for the reception of the various mechanisms that are to be assembled on the sides and on the bottom at the front and in the rear for attaching to the racer. With the exception that these operations involve the handling of a very heavy piece of machinery, there is nothing unusual or difficult involved. Each of these two castings weighs 34,000 pounds. The racer is cast, as already explained, in four parts,

PLATE 144.



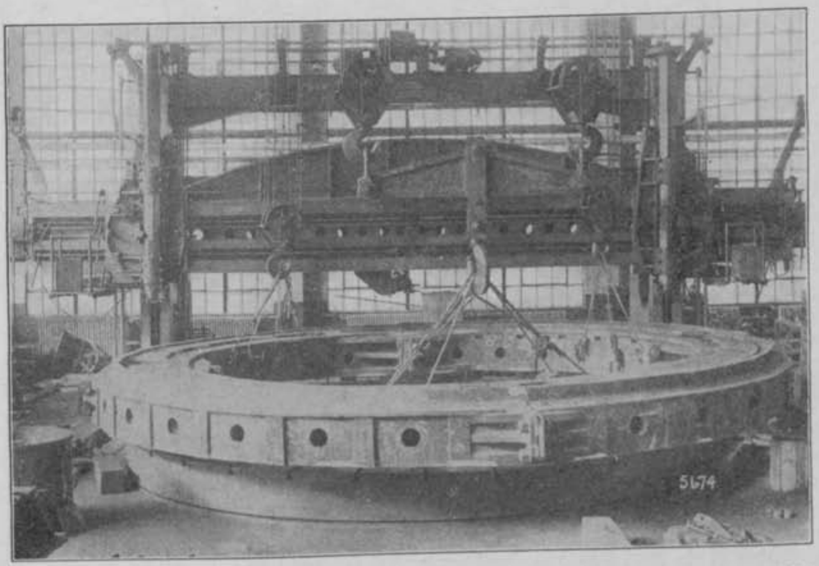
FINISHING BOTTOM SURFACE OF RACER SECTION ON PLANER.

each part machined separately for joining to two other parts on the top for the placing of the side frames or girders and on the bottom for the cone roller bearing. These operations are shown in Plates 144 and 145. The assembled racer without the side girders attached is shown in Plate 145. Its total weight is 200,000 pounds. The operation of machining the roller bearing, of course, requires the racer to be assembled into one piece. This machining is done on a large boring mill, as shown in Plate 145.

240. *Traversing mechanism.*—The design of the traversing mechanism was started with the requirements that the ratio of motion of the handwheel to traversing of the carriage be from 324 to 360

turns per 360 degrees for the fast-motion mechanism and approximately 3,600 turns per 360 degrees for the slow-motion mechanism. The limitation of 30 pounds for the handwheel load was set up, and the total load to be carried, together with the coefficient of friction of this type of bearing, were known. It was decided again to avoid the use of worms and worm wheels and use only spur gearing. The design of this mechanism as finally worked out is shown on Plates 146–154. A photograph of the mechanism assembled is shown on Plate 132. The only portion of the mechanism which does not show in this figure is the pinion on the lower end of the vertical shaft which meshes with the rack on the base ring. The design involved

PLATE 145.



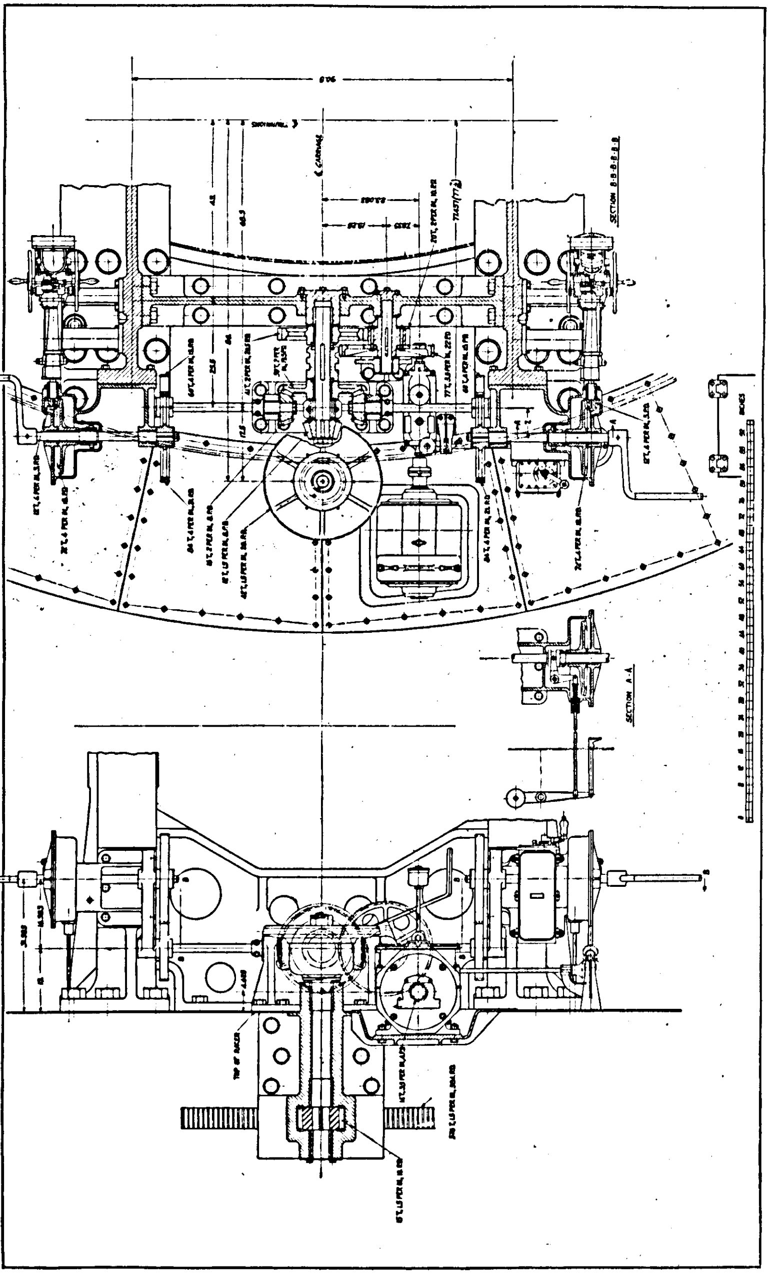
PREPARING TO MACHINE THE ROLLER PATH OF ASSEMBLED RACER, CASTING SHOWN INVERTED.

the incorporation of a Waterbury spring gear, so that the mechanism might be driven at varying speeds by means of an electric motor as well as by hand if necessary.

241. On Plate 149 the conical steel rollers used in this traversing mechanism are shown in assembly. They are 42 in number, are of forged steel A, and are not hardened. They are provided with short spindles by which they are held properly in place by a distance ring.

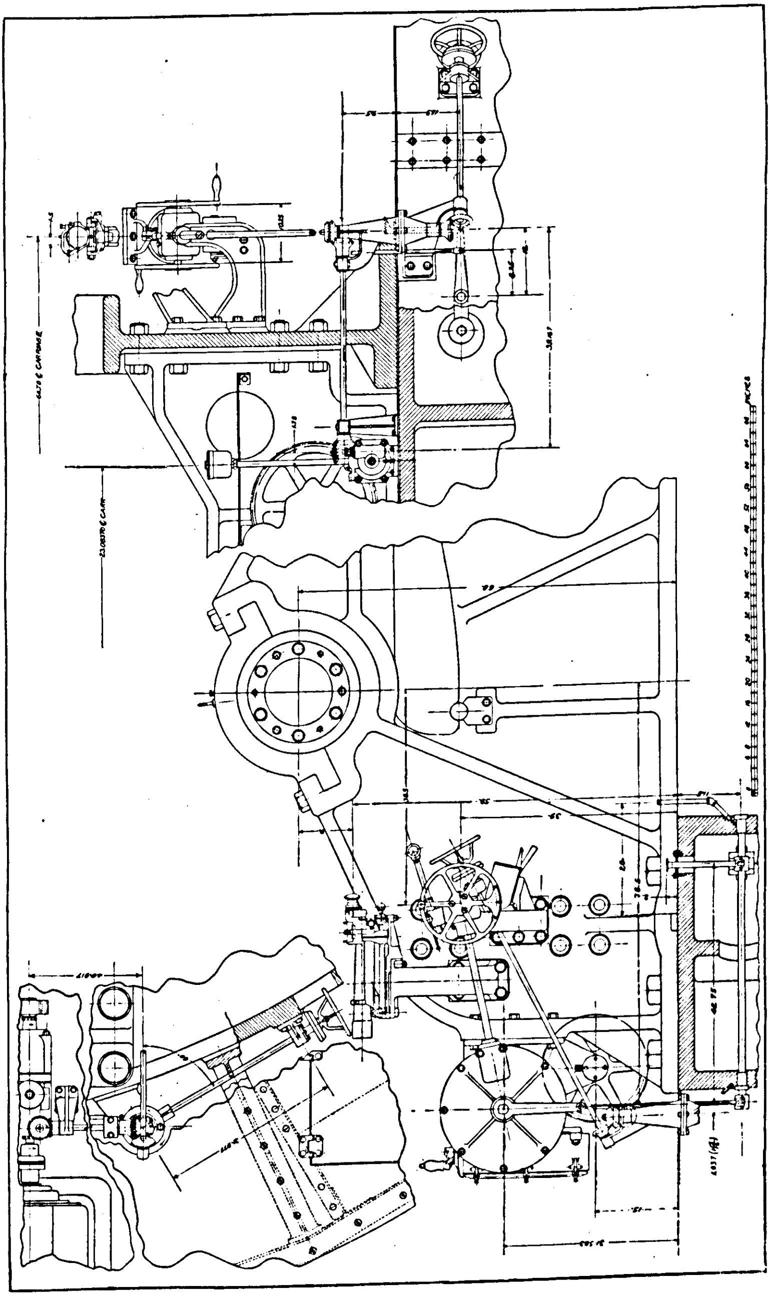
242. *Manufacture.*—There is nothing unusual in the manufacture of any of the parts of this mechanism, since it involves simply the use of spur and beveled gears. The rack which is attached to the circumferences of the base ring is made in 12 parts and attached to

PLATE 146.



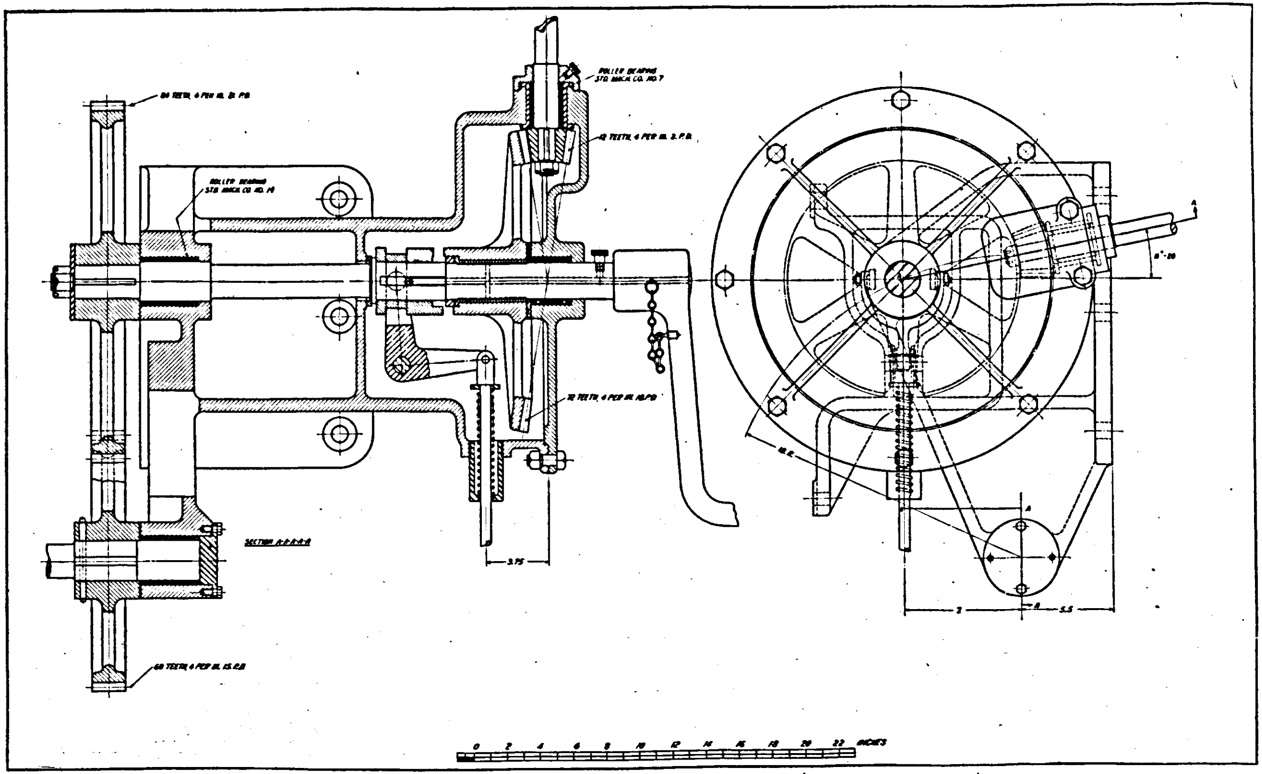
TRAVERSING MECHANISM ASSEMBLY OF 16-INCH BARBETTE CARRIAGE, MODEL OF 1919.

PLATE 147.



SLOW-MOTION MECHANISM AND SPEED GEAR CONTROL OF THE TRAVERSING GEAR.

PLATE 148.

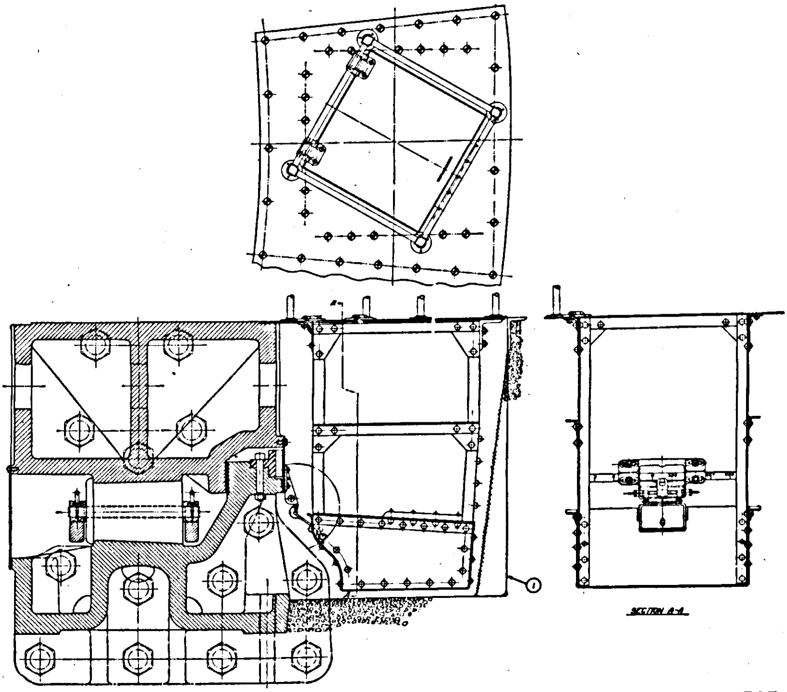


CLUTCH ASSEMBLY ON FAST MOTION CRANK SHAFT FOR SLOW SPEED MECHANISM.

the ring by means of screws. When completed it was found that a maximum handwheel load of 27 pounds was required to operate the high-speed mechanism. A much less load is required for the slow-speed mechanism.

243. *Loading mechanism.*—In designing the loading mechanism, Plates 155–158, the factors that were given were the weight of the projectile, the weight of the powder charge and approximate design of the ammunition storage house in its relation to the gun, and the desired speed of loading and rate of fire. The weight of the pro-

PLATE 149.



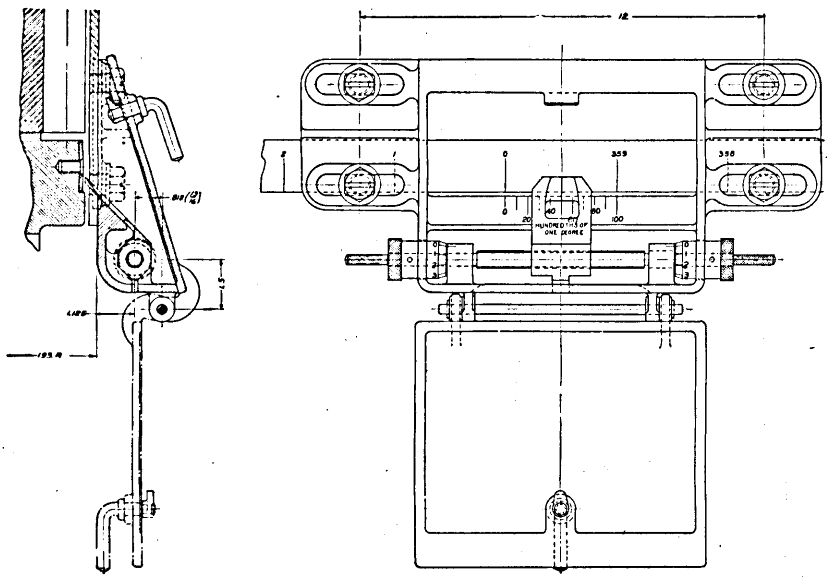
SECTION THROUGH BASE RING AND RACER SHOWING AZIMUTH INDICATOR, CIRCLE, AND OBSERVER'S CAB.

jectile, 2,400 pounds, is such as to make power loading and ramming quite desirable. The rate of firing specified as desired was 1 shot per minute.

244. Investigation of existing methods of handling ammunition of this size revealed the mechanisms employed in the Navy for the elevating of the projectile from subdeck storage rooms to the turret and by mechanical means into the gun. It was deemed desirable to have the truck operated by power rather than by hand, and for this purpose storage batteries and electric motors, reciprocating engines, and compressed air were considered. It seemed finally that it would

be better to avoid the use of a storage battery and electric motors with the resultant danger from the presence of the powder charge. and a truck of the design shown on Plate 156 was decided upon. It will be observed here that the truck receives 3 projectiles from the magazine platform and is then pushed by a gas locomotive to the mount. The gun is loaded at the position of plus 4 degrees, the projectile being rammed by hand or power, Plates 155–158. The powder truck carries 12 sections or 3 charges. Two sections are transferred to the loading table and rammed at a time. The igniter is then put in behind the last quarter charge by hand.

PLATE 150.

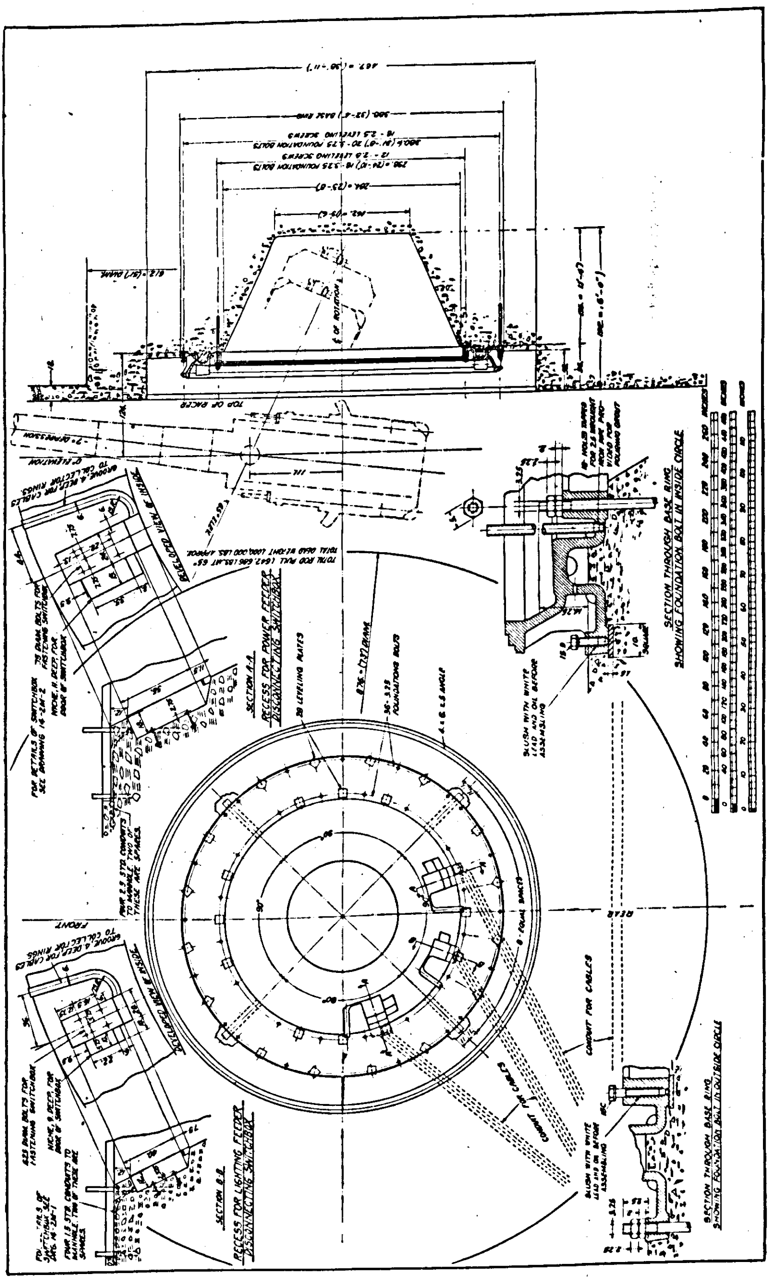


PORTION OF AZIMUTH CIRCLE AND INDICATOR WITH VERNIER ADJUSTMENT.

245. The gun, carriage, and loading mechanism as designed part by part and described briefly in the preceding paragraphs is shown partially and completely assembled in Plates 132, 159, 160, and 161. It is shown assembled at the proving ground for proving of the gun and carriage in Plate 162. Attention is called to the comparison of the size of this carriage and the disappearing carriage for the same gun. The cost of the disappearing carriage is considerably greater than that of the barbette carriage, and permits an elevation of only 30 degrees as against the 65 degrees of the barbette carriage, and during its lifetime probably will cost several times as much in maintenance as its smaller competitor.

246. It was pointed out at the beginning of this discussion of the design and manufacture of such a seacoast weapon that it would be impossible to discuss in very great detail the mathematical design of

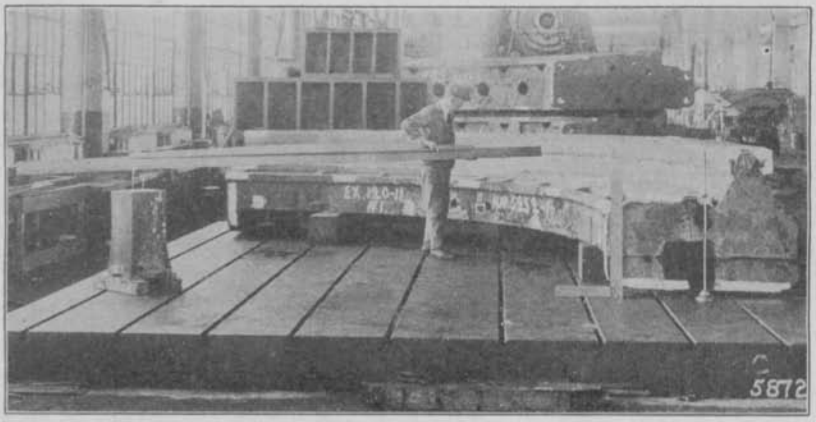
PLATE 151.



EMPLACEMENT OF THE 16-INCH BARBETTE CARRIAGE MODEL OF 1919.

the various parts because an excessive amount of space would be required; and, after all, no particularly good purpose would be served, because the student of this volume is not so much interested

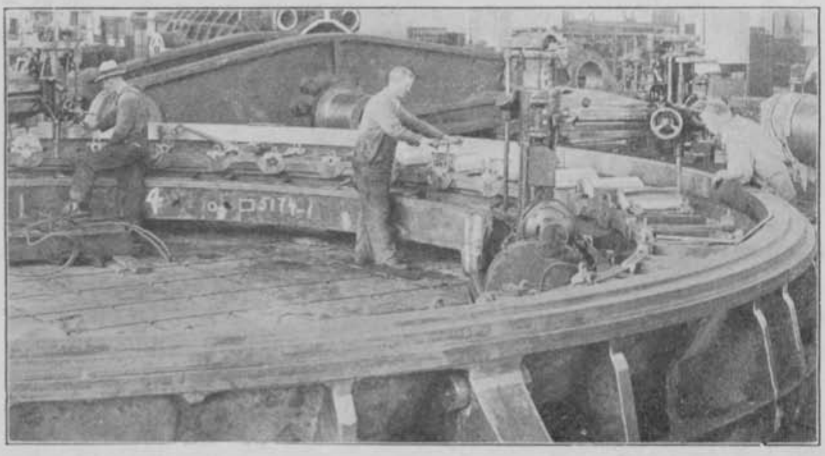
PLATE 152.



LAYING OFF SURFACES FOR MACHINING OF QUARTER SECTION OF BASE RING.

in the elaborate mathematical design of the various components as he is in the brief discussion of the factors involved in the design and a general analysis of the requirements and a discussion of the forces

PLATE 153.



ASSEMBLING THE ROLLER UNIT ON PATH OF BASE RING.

involved. Any who are interested in the minute detailed discussions of the design of the various parts of such a carriage can find the complete designs, calculations, etc., as worked out by the designers

in the Offices of the Railway and Seacoast Carriage Section, Artillery Division, Office of the Chief of Ordnance, Washington. Notes with

PLATE 154.

BOLTING ON THE TRAVERSING RACK ON BASE RING.

reference to the minute details of the processes of manufacture of the various parts of the gun will be found at Watervliet Arsenal, and

PLATE 155.

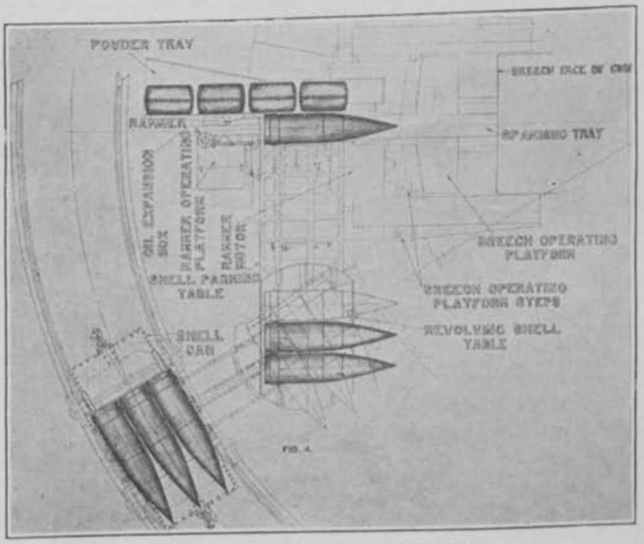
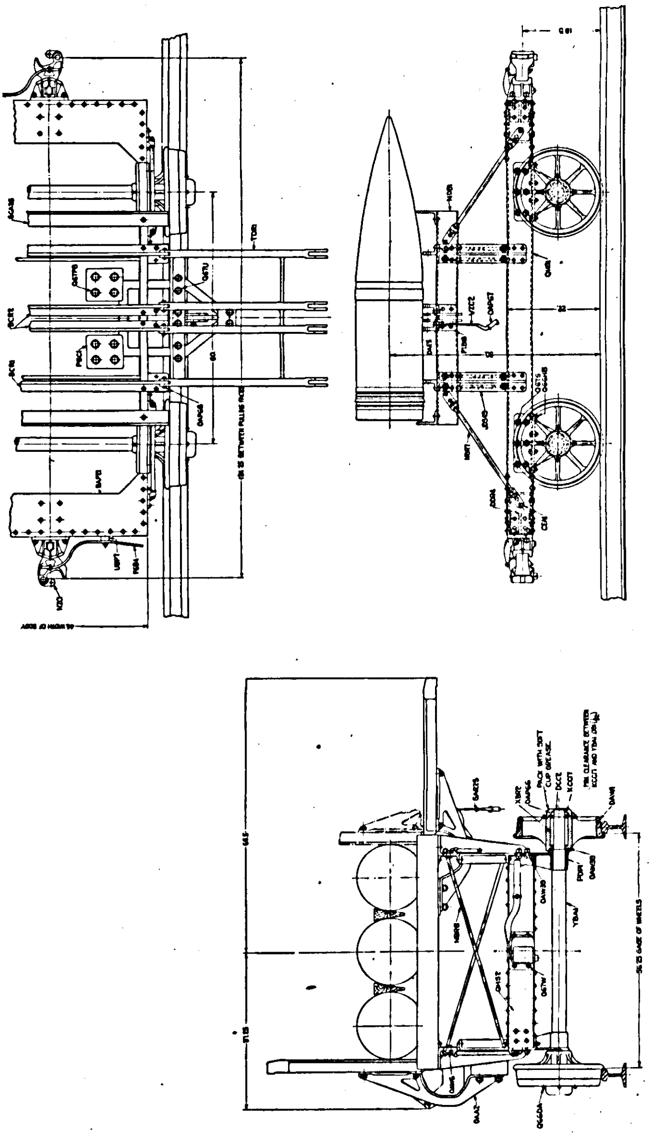


DIAGRAM OF LOADING METHOD.

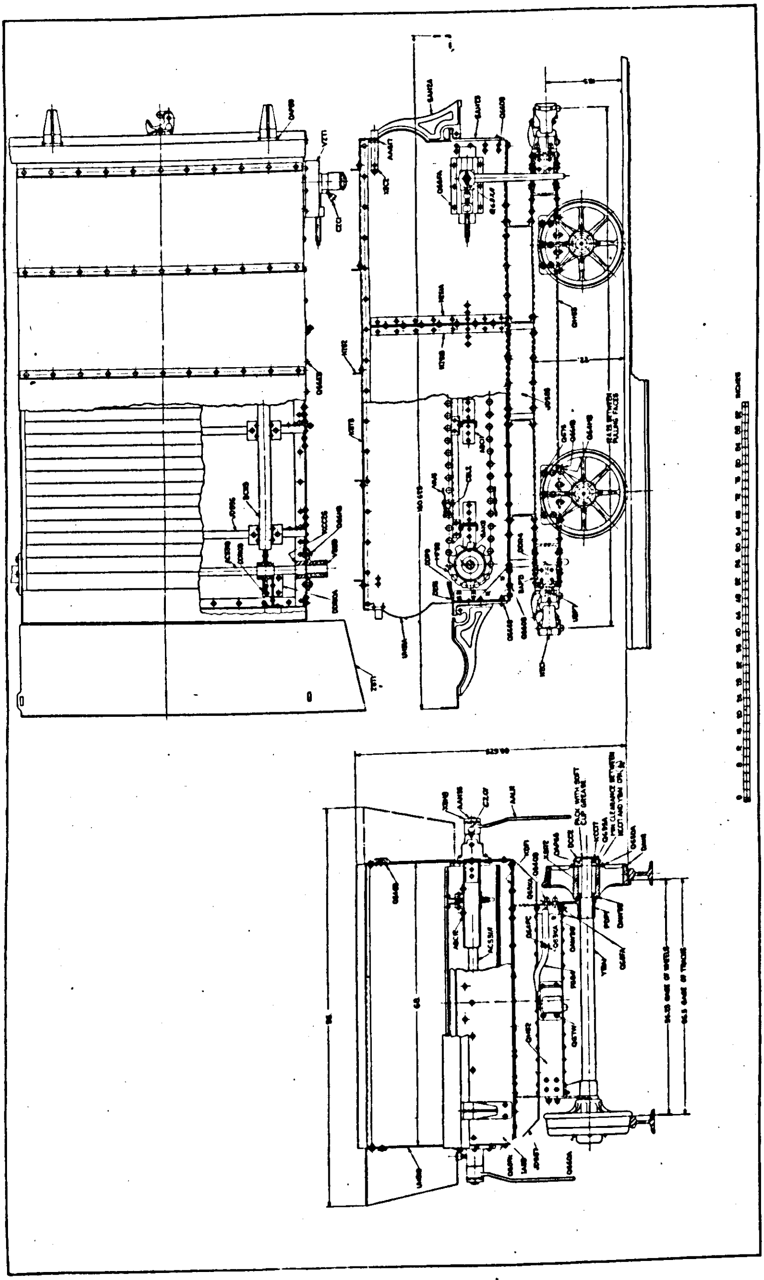
similar notes with reference to the details of the processes of manufacture of the carriage will be found at Watertown Arsenal.

PLATE 156.



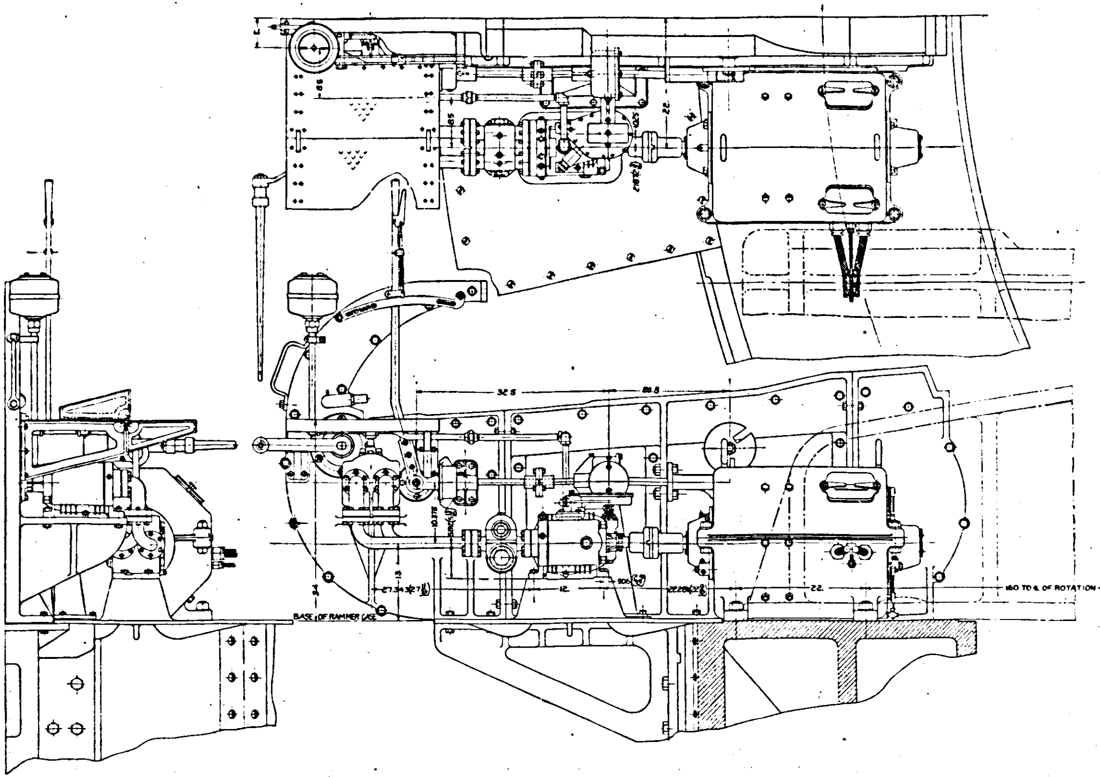
CAR FOR DELIVERING 16-INCH SHELLS FROM MAGAZINE TO MOUNT.

PLATE 157.



THREE-CHARGE POWDER CAR OF THE 16-INCH BARBETTE CARRIAGE.

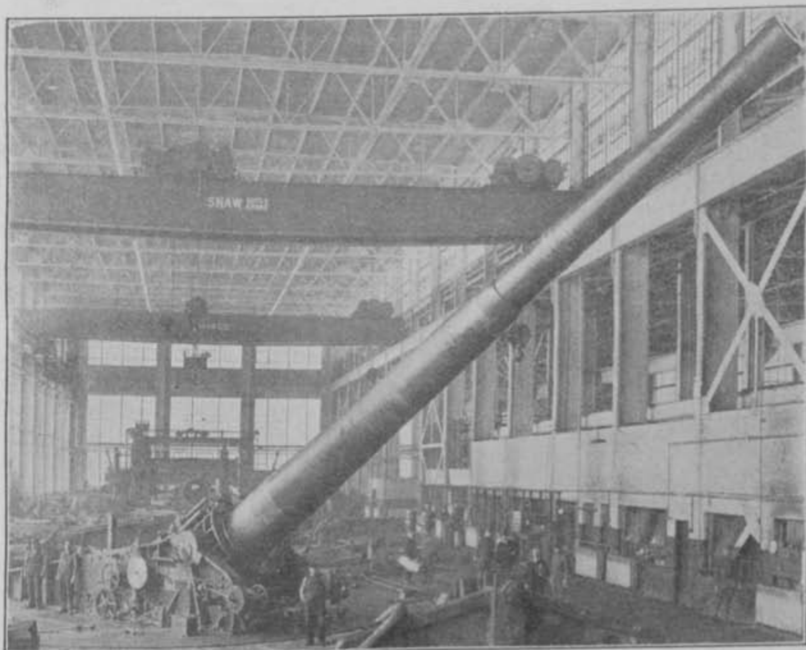
PLATE 158.



ASSEMBLY OF THE POWER RAMMER UNIT.

247. It was pointed out in the beginning that a great deal of the design involved in the devising of such a machine is necessarily handled as one proceeds. Consideration of the discussion just given shows how true this is. In the original requirements it was not possible to specify the length of recoil because it was realized that this had a vital relation to the stresses that would be set up in the various parts of the carriage and would consequently affect the design of the parts as to weight and strength. It has a definite relation likewise to the size of the racer and base ring, and a rather detailed study was required to determine what the limits of diameter

PLATE 159.

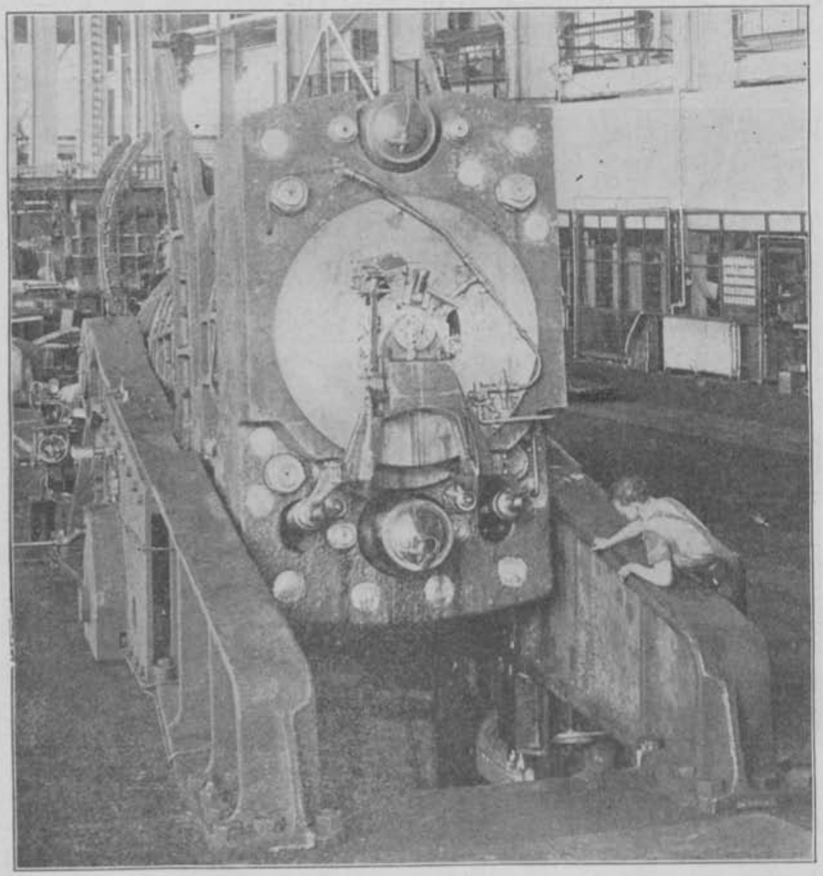


16-INCH CARRIAGE, FINISHED AND ASSEMBLED IN THE ARSENAL.

of these rings should be. This applies to many parts of the carriage, and as a consequence only the most vital requirements and characteristics of the gun and carriage can be decided upon in the beginning.

248. It is interesting to speculate what the next development will be in guns and carriages beyond this design, which is unquestionably the most powerful weapon in the world at the present time. Already we are considering guns of 18-inch caliber. This means the consideration of the weight of projectile, muzzle velocity, weight of powder charge, etc. By the time we have reached a decision to

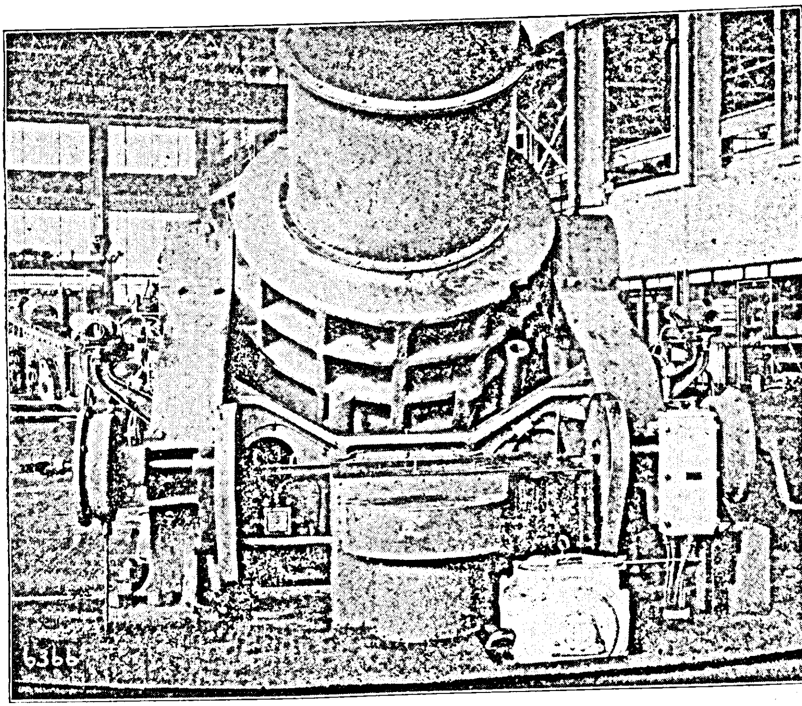
PLATE 160.



REAR VIEW OF ASSEMBLED MOUNT.

construct such a gun and carriage probably the metallurgists will have produced a steel of greater tensile strength, and the design of the gun made of such a steel will not be the same as that just produced from the steel in use at this time. The action of this carriage will be studied carefully, and from time to time improvements will be suggested, faults will be found, and new conditions will arise that must be met. It is not impossible that we are seeing here almost the limit of the development of coast defenses of this type. If it is

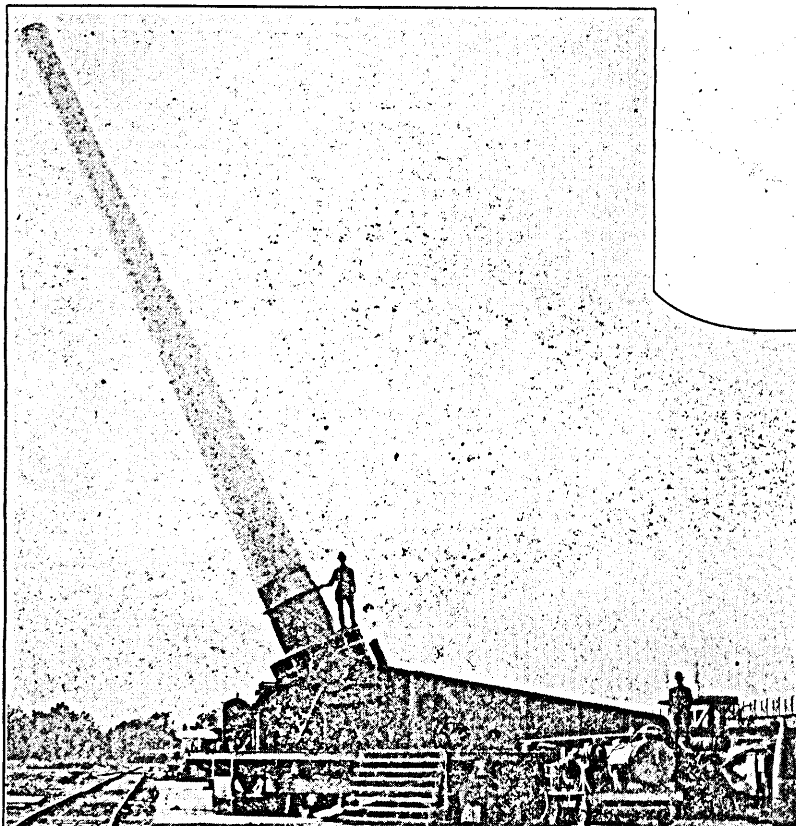
PLATE 161.



FRONT VIEW WITH CRADLE AND GUN ELEVATED.

true that the end of the great warships is in sight through the growing efficiency of the airplane and through the decisions of the Conference on Limitation of Armament, it may be that we are now writing the story of the entire development of this character. Guns and carriages of this description are of no value against submarines; and if the warship is to pass and submarines and airplanes are to take its place, it is difficult to foresee the need of more powerful weapons of this description. The attention of the student of 10 or 20 years hence is invited to this paragraph for the interest that it will afford him in studying the development that has taken place during that time.

PLATE 162.



MOUNT AT PROVING GROUNDS—GUN ELEVATED TO 65 DEGREES.

Part III.

THE MECHANISMS OF EXISTING SEACOAST WEAPONS.

249. In Part I a relatively complete history has been given of the development of each distinct part or mechanism of a gun and its carriage from the time of the first use of the crudest form of such mechanisms as exist to-day down to the latest development of which we have any knowledge. Part II deals with the problems involved in determining the requirements of a modern great seacoast weapon, the general procedure in designing, and the problems and procedure involved in the manufacture. Having dealt with the history of the development of the various mechanisms and the problems involved in design, manufacture, etc., it is now pertinent to proceed with a discussion or description of the various mechanisms on weapons in use at the present time. It has not been possible, and it does not seem desirable, to attempt to give in this volume detailed descriptions of the various mechanisms in use on weapons that have passed out of service. The student of Part I has probably found that each step in the development of any particular mechanism has involved largely the refinement in design, manufacture, or properties of materials. Taken over a period of years, the development represents improvement in all three respects. We are hence concerned at the present time most with the characteristics of the mechanisms that are in use to-day. Our appreciation of the perfection of these mechanisms at this time is simply enhanced by a knowledge and appreciation of the various steps that have occurred in the development of the past centuries. Fifty years hence the mechanisms that we are describing here may appear as crude as those of 50 years ago appear to us now, especially if one may judge by the progress that has been made in the last 8 years.

250. In describing the mechanisms of the various weapons that have been selected as typical and that are listed in the table below it will be the procedure to describe each typical mechanism but once; for example, in describing the recoil mechanism of the 16-inch 50-caliber gun, which will be dealt with first, each mechanism will be described in rather elaborate detail. In taking up the descriptions of the 12-inch gun on its barbette carriage only those mechanisms will be described in detail which are fundamentally or noticeably

unlike the similar mechanisms contained in the 16-inch unit. If the recoil cylinder proper of the 12-inch carriage is the same in principle as well as construction as any of the cylinders of the 16-inch carriage, merely a reference will be made to the fact that this mechanism or cylinder is identical with that described in paragraph X. It is believed that this procedure will not only properly conserve space, but will likewise serve to point out more clearly to the student to what extent the various mechanisms on carriages large and small are identical in principle and construction.

Table of weapons described in this part.

Cannon.				Carriage.	
Description No.	Caliber.	Length.	Model.	Type.	Model.
1	16-inch	50-caliber, gun	1919, MII	Barbette	1919.
2	16-inch	50-caliber, gun	1919	Disappearing	1917.
3	16-inch	25-caliber, howitzer	1919	Barbette	1920.
4	16-inch	35-caliber, gun	1895	Disappearing	1912.
5 and 5a.	14-inch	34-caliber, gun	1907, 1907 MI and 1910.	do	1907 and 1907 MI.
6	14-inch	40-caliber, gun	1909	Turret	1909.
7	14-inch	40-caliber, gun	1919	Railway	E.
8	14-inch	50-caliber, gun	1920	do	1920.
9	12-inch	10-caliber, mortar	1908	Mortar	1908.
10 and 10a.	12-inch	15-caliber, mortar	1890 and 1912	do	1896 MI, MII, MIII.
11	12-inch	35-caliber, gun	1895 MI	Barbette	1917.
12	12-inch	34-caliber, gun	1888 MI, MII	do	1892.
13	12-inch	40-caliber, gun	1895 and 1900	Disappearing	1901.
14	12-inch	35-caliber, gun	1895	do	1897.
15	12-inch	34-caliber, gun	1888 and 1895	do	1896.
16	12-inch	35-caliber, gun	1895	Railway	1918.
17	12-inch	10-caliber, mortar	1890	do	1918.
18	12-inch	20-caliber, howitzer	1919	do	1918.
19	10-inch	35-40-caliber, gun	1895, 1900	Disappearing	1901.
10	10-inch	34-35-caliber, gun	1888, 1895	Disappearing, A. R. F.	1896.
21	10-inch	34-35-caliber, gun	1888, 1895	Disappearing, L. F.	1896.
22	10-inch	34-caliber, gun	1888	Disappearing	1894. MI.
23	10-inch	34-caliber, gun	1888	Barbette	1893.
24	8-inch	32-caliber, gun	1888	do	1892.
25	8-inch	32-caliber, gun	1888 MI, MII	Disappearing	1896.
26	8-inch	32-caliber, gun	1888	Railway	1918.
27	6-inch	50-caliber, gun	1905, 1908	Disappearing	1905 MII.
28	6-inch	50-caliber, gun	1903, 1905, 1908	do	1905 MI.
29	6-inch	50-caliber, gun	1905	do	1905.
30	6-inch	50-caliber, gun	1900, 1903, 1905	do	1903.
31	6-inch	44.5-caliber, gun	1897 MI	do	1898.
32	6-inch	50-caliber, gun	1908 MII	Barbette	1910.
33	6-inch	50 caliber, gun	1900	do	1900.
34	6-inch		Armstrong	do	Armstrong.
35	4.7-inch	22-caliber, howitzer	1913	Railway	1915.
36	3-inch		1903	Barbette	1903.
37	3-inch		Bethlehem	do	1902.
38	3-inch	50-caliber, gun	1898	do	1898 MI.

251. The order in which the various mechanisms will be described is as given below. It will be observed that each mechanism is listed with a certain number. The first cannon that is described, which is listed as No. 1, will be classified as A. All other cannon of similar or identical construction will merely be compared with cannon A. As soon as a cannon of a fundamentally or radically different construction is encountered in the list it will be described under the head of B, and other cannon of a similar construction will have merely a refer-

ence to this detailed description. This procedure will be followed with reference to each distinct type of mechanism. Where any particular mechanism differs only slightly but sufficiently to warrant calling attention to the difference it will be described under a new classification, but the previous description of those parts which are identical will not be repeated.

Order of description of mechanisms.

1. Cannon.
2. Breech mechanism.
3. Firing mechanism.
4. Recoil mechanism.
5. Recuperator mechanism.
6. Elevating mechanism.
7. Traversing mechanism.
8. Loading mechanism.
9. Chassis and (or) top carriage.
10. Base.

1. THE 16-INCH 50-CALIBER GUN, MODEL OF 1919 MII, ON BARBETTE CARRIAGE, MODEL OF 1919.

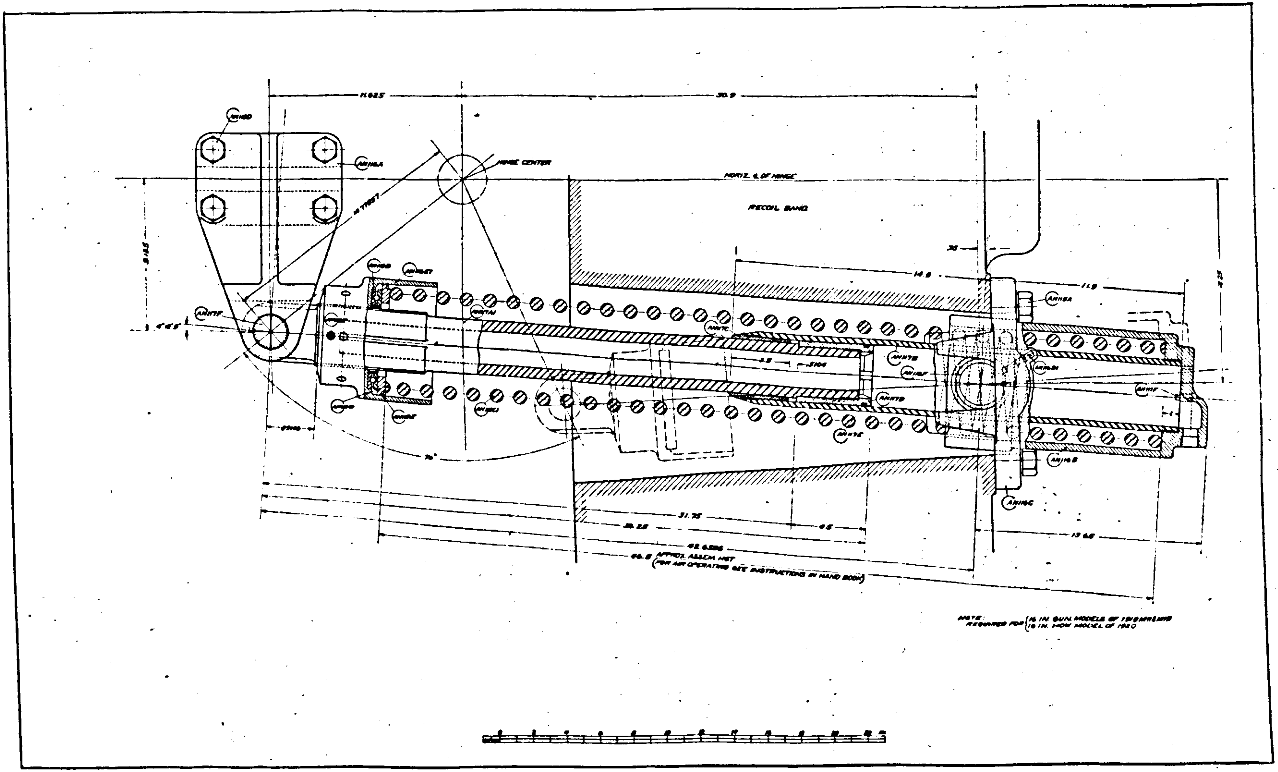
252. *Cannon A.*—The 16-inch 50-caliber gun is shown in section on Plate 99, Part II. It will be observed here that the gun is of the wire-wound type and comprises a B tube and jacket over which the wire is wound and locked by the various locking rings. A series of hoops are then shrunk on over this wire, and when this outer portion is completed the entire gun is heated and shrunk over the A tube. A shoulder is machined on hoop E, against which the heavy counterweight, which is assembled mechanically, Plate 140, bears as the gun recoils. The powder chamber is cylindrical in form, has a maximum diameter of 22 inches, a length of 121.263 inches, and a capacity of 40,000 cubic inches. The bore of the gun is rifled with 144-inch grooves having a width of 0.2091 inch and a depth of 0.12 inch. The lands have a width of 0.14 inch. The twist of the rifling varies from one turn in 50 calibers at the origin to one in 25 calibers at the muzzle, and the velocity of rotation of the projectile as it leaves the muzzle is 1,620 revolutions per minute. The breech ring is machined to 4 diameters and divided into 4 groups of 4 segments each to accommodate the step-threaded Welin breechblock. The 4 unthreaded sectors are of course of the largest diameter. The total weight of the gun without the counterweight is 340,600 pounds and its total length is 826.8 inches. Most of the material used in the construction of the gun is alloy nickel-steel having an elastic limit of approximately 65,000 pounds. The A and B tubes have an elastic limit of 55,000 pounds each. The wire used is one-tenth of an inch square, is cold-rolled alloy steel, and is wound on at the uniform stress of 50,000 pounds per square inch. As finally assembled the A tube is under a compression of about 60,000 pounds per square inch. The approximate droop of the gun is 0.6 inch at zero elevation and as supported in the cradle of the barbette carriage.

253. *Breech mechanism A.*—The breech mechanism, Plate 121, comprises a block, a mushroom head with spindle, a carrier or hinge to which the block is attached and on which it swings back and down, and the combined buffer and closing cylinder mounted directly under the breech of the gun. It will be observed that this breech mechanism is of the Welin step-thread type, the entire circumference being divided into 16 segments, 4 of which are unthreaded. The block is machined to 4 different diameters, the least diameter being reserved for the unthreaded segments, and the other 3 diameters are threaded with a V-thread to fit the corresponding threaded segments of the gun. This type of breech offers the advantage of making it possible to close or open the block by a one-sixteenth rotation of its axis. This relatively small degree of rotation required for opening and closing makes it possible to substitute a considerably more simple and more rapid operating mechanism for the opening and closing. In the typical breech mechanisms of the models of 1888 and 1895 the threading of the breech to 1 diameter has necessitated the use of a rather laborious opening and closing mechanism comprising worms and combination or compound worm and spur gears, which serve chiefly to rotate the block and then withdraw it along the axis of the gun to such a point that it may be swung to the side on its hinge. The slight rotation of this block accomplished through the plug handle serves, first, to release the breech from the gun and, second, by the slight pull to the rear to start it on its swing to the rear and down. In closing the breech, the block carrier is actuated by the air cylinder and, in the last part of the movement, two small rollers on the block strike a cam surface on the breech face, thus imparting a rotary motion sufficient to engage it in the breech threads, and press the obturator pad firmly into the gas-check seat of the powder chamber. This rotary motion causes the lever used in opening the block to automatically swing up and latch in place.

254. The buffer and closing mechanism, Plate 163, comprises simply an air cylinder, piston, and a buffer spring. When the block is released after firing and drops, its motion is checked through the action of the spring. When it is desired to close the block, air is introduced into the cylinder, which, through the push of the piston, swings the block up into place and holds it there until it has been rotated and locked.

255. An accessory in the shape of an air ejector for the powder gasses is added, probably more as a carry over of the practice of the Navy rather than as a result of any feeling on the part of the Army that it is necessary. When such guns as these are in use on a battleship it is, of course, most desirable that on opening the breechblock the gasses be not permitted to flow back into the turret. As a conse-

PLATE 163.



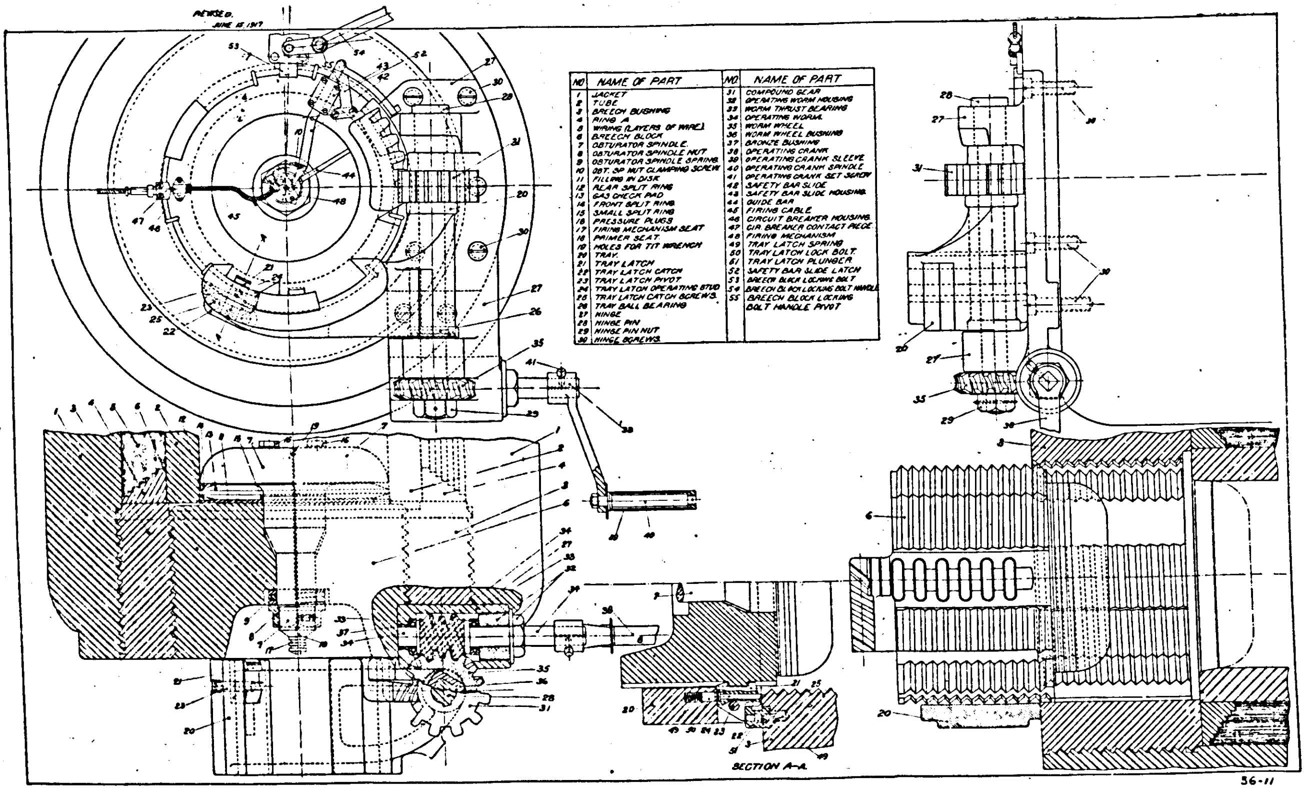
BUFFER FOR THE DROP-BLOCK TYPE OF BREECH MECHANISM.

quence, a semi-automatic type of gas ejector is generally introduced which, on the opening of the block, permits air at rather high pressure to flow through several orifices in the wall of the breech bushing, driving the powder gasses forward and out of the gun. Since the air was supplied for use in the closing cylinder in this case the gas-ejecting feature has been included.

256. The mushroom head, split rings, and obturation or gas-check pad used with block, Plate 121, are not unlike the similar components of the more common or single-threaded diameter blocks, Plate 164. The gas-check pad is made of oiled asbestos and covered simply with canvas or with woven copper cloth or perforated sheet copper, and the whole compressed under tremendous pressure to the desired form. Such pads render satisfactory service in the laboratory service, speaking relatively, of coast defenses or battleships. They are not entirely satisfactory in field service, as learned to our displeasure in the past war. The mushroom head is provided primarily to serve as a pressure plate for expanding the obturator pad against its seat in the gun and as it receives extreme punishment from the heat and pressure of the main powder charge and erosion in the vent from the primer gasses it is designed to be easily replaced if necessity arises.

257. *Firing mechanism A.*—The firing mechanism of this breech, Plate 165, comprises essentially a machined seat and holder for the percussion or electric primer, as the case may be. It is not probable that it would be desired to use any friction primers with a gun of this type, though there is no fundamental reason why this could not be done. When electric primers are used the current is supplied from a high-voltage battery of the type normally termed a firing battery and used both with artillery and for commercial blasting. In this case the battery used will be power driven instead of hand, but the principle of operation is the same. The primer is fired in this case simply through the heating of a small wire in the primer connecting the ends of the leads from the battery. When percussion primers are used the lanyard is connected to the sear, which, on being pulled to the rear and down, withdraws the hammer plunger and permits the firing pin to be driven forward by a spring, striking and firing the primer. There are numerous modifications of this percussion firing mechanism, some of which involve the use of a separate primer holder, which, in effect, is nothing but a small plug several inches in diameter with a slot in its front end to receive the head of the primer. This plug has a rather steep thread and is screwed into the rear end of the spindle by a turn or two and is locked by a special locking device. Frequently the plug contains the striking pin also, which is driven forward by means of a spring

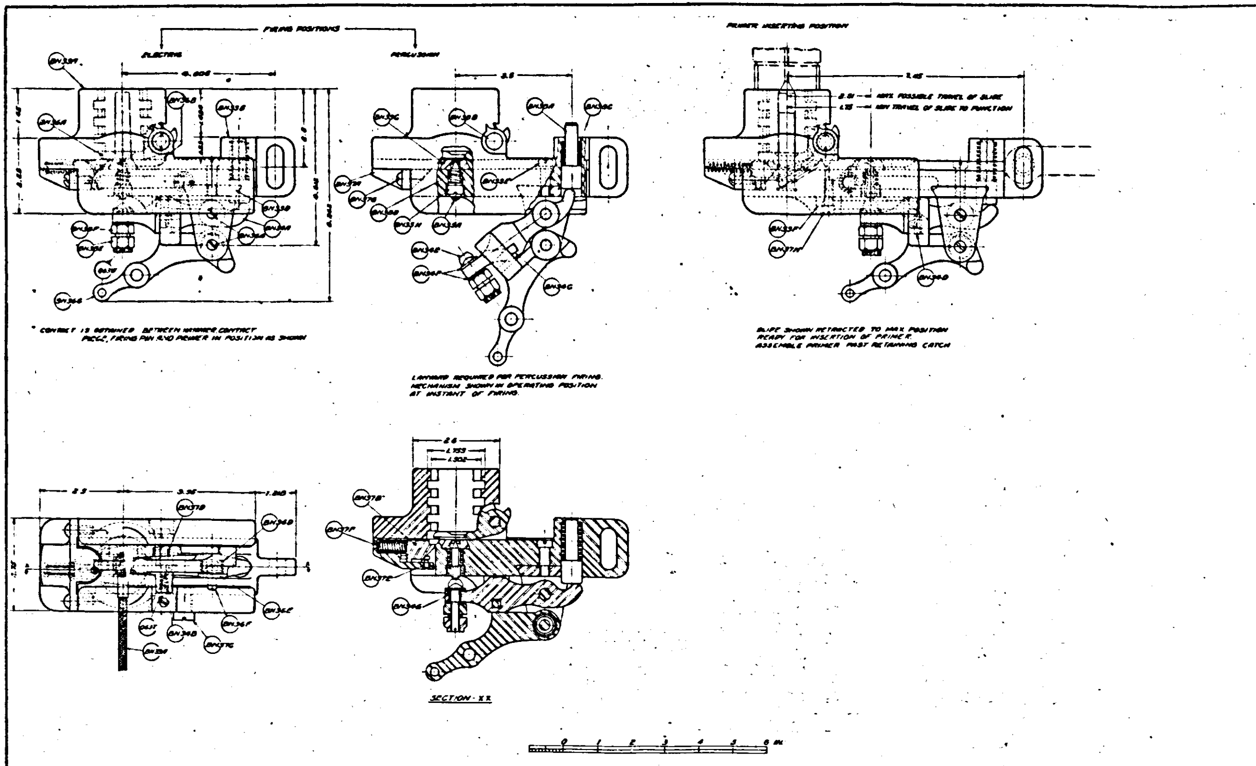
PLATE 164.



NO	NAME OF PART	NO	NAME OF PART
1	JACKET	31	COMPOUND GEAR
2	TUBE	32	OPERATING WORM HOUSING
3	BREECH BUSHING	33	WORM THRUST BEARING
4	RING A	34	OPERATING WORM
5	WIRING (LAYERS OF WIRE)	35	WORM WHEEL
6	BREECH BLOCK	36	WORM WHEEL BUSHING
7	OBTURATOR SPINDLE.	37	BRONZE BUSHING
8	OBTURATOR SPINDLE NUT	38	OPERATING CRANK
9	OBTURATOR SPINDLE SPRING	39	OPERATING CRANK SLEEVE
10	OBT. SP. NUT CLAMPING SCREW	40	OPERATING CRANK SPINDLE
11	FILLING IN DISK	41	OPERATING CRANK SET SCREW
12	REAR SPLIT RING	42	SAFETY BAR SLIDE
13	GAS CHECK PAD	43	SAFETY BAR SLIDE HOUSING
14	FRONT SPLIT RING	44	GUIDE BAR
15	SMALL SPLIT RING	45	FIRING CABLE
16	PRESSURE PLUGS	46	CIRCUIT BREAKER HOUSING
17	FIRING MECHANISM SEAT	47	CIR. BREAKER CONTACT PIECE
18	PRIMER SEAT.	48	FIRING MECHANISM
19	HOLES FOR TIT WRENCH	49	TRAY LATCH SPRING
20	TRAY.	50	TRAY LATCH LOCK BOLT.
21	TRAY LATCH	51	TRAY LATCH PLUNGER.
22	TRAY LATCH CATCH	52	SAFETY BAR SLIDE LATCH
23	TRAY LATCH PIVOT	53	BREECH BLOCK LOCKING BOLT
24	TRAY LATCH OPERATING STUD	54	BREECH BLOCK LOCKING BOLT HANDLE
25	TRAY LATCH CATCH SCREWS.	55	BREECH BLOCK LOCKING BOLT HANDLE PIVOT
26	TRAY BALL BEARING		
27	HINGE		
28	HINGE PIN		
29	HINGE PIN NUT		
30	HINGE SCREWS.		

BREECH MECHANISM OF THE 16-INCH 50-CALIBER GUN FOR DISAPPEARING

PLATE 165.



FIRING MECHANISM OF THE 16-INCH 50-CALIBER GUN.

after it is released by the latch through a pull of the lanyard. A slight modification of this mechanism which is in rather general use in the French service involves the use of a spring loop attached to the firing pin through a short 6-inch section of light cable. A hook on the end of the lanyard is passed through this loop, and when the firing pin is drawn back and the pull on the lanyard increased, the ends of the loop separate, permitting the hook to pass between them. The striker is then driven forward by the spring and fires the primer. Electric firing mechanisms generally comprise simply a satisfactory holder or recess for a primer which is exploded or fired through the medium of a heated iron wire and electric current.

258. *Recoil mechanism A.*—The recoil mechanism of this carriage comprises two cylinders, Plate 124, of a type common on our seacoast carriages for many years and two other cylinders and mechanisms, Plate 123, of a type new and peculiar to this carriage. The two short cylinders comprise each a forged-steel cylinder set into the proper brackets of the cradle and closed at the front end by a plug and provided at the rear end with the necessary gland and stuffing box for the passage to the rear of the piston rod, which is connected to the combined counterweight and recoil band of the gun. The piston rod is made of steel and has screwed and locked to its forward end a bronze piston. The walls of the cylinder are machined with 3 grooves of the usual type, through which the oil passes at varying velocities as the gun recoils. Assuming that this book is being used by those who are not entirely familiar with all of the details of such a mechanism, as well as by those who are, we may perhaps mention that the gun is brought to rest through the resistance opposing the passage of the oil past the piston from one end of the cylinder to the other. The grooves machined in the wall of the cylinder are of uniform width but varying depth, varying according to the force being exerted by the gun or pull on the piston rods as the gun attempts to move to the rear. The energy of recoil of the gun is finally dissipated through mechanical friction and through the friction of the liquid passing through the orifices in the grooves when the piston reaches the position shown by dotted lines. The oil by this time has been transferred from one side of the piston to the other, and the gun is momentarily at rest. As the gun moves forward due to the pull exerted by the recuperators, the oil slowly passes back through the grooves until the piston is again in position at the forward end of the cylinder, as shown by the full lines. It will be observed that there is no special mechanism provided under the name of a counter-recoil buffer to retard the motion of the gun forward or to prevent its banging or charging into battery.

259. The other two recoil cylinders illustrated in Plate 123 are unique and new with this gun and are worthy of special attention. If we consider in the upper view only that portion of the cylinder from the piston which is located about in the center of the cylinder to the rear or the left, we find a mechanism practically identical with the one just described. Identical grooves are machined in the walls of the cylinder, through which the oil passes as this piston moves to the left. The portion of the cylinder to the right of the center, however, is unique. When the gun is finally brought to rest in its motion to the rear and is then returned to its firing position or to battery by the pull of the recuperator, unless some special device is provided to serve as a buffer, the gun is very apt to strike the carriage with such force as to endanger the entire mechanism. This condition would not necessarily prevail if the gun were always fired at one elevation, and this fact could be taken into account in its design. Under such conditions the recoil grooves could probably be so designed as to serve as buffers and produce a cushioning effect on return to battery. Guns are not fired at fixed elevations, however, and buffers which are provided must be made to operate if possible as satisfactory at zero elevation or angles of depression, where the force of gravity is added to the pull of the recuperators, as at the maximum elevation where the force of gravity subtracts from the pull of the recuperators. The older type of buffer, which usually comprised a conical plug attached to the forward end of the recoil piston rod, Plate 227, has not served with equal satisfaction at zero and 45 degrees elevations. When it was decided that in this case the gun should have a range of elevation of —7 degrees and +65 degrees, the conditions were so extreme as to prohibit at once the use of the old type of buffer. Trials made with the old type of buffer on guns operating at these elevations showed clearly that some new type would have to be devised for this gun. The recuperating effort required at an elevation of 65 degrees would be so much more than is necessary at —7 degrees that the excess energy could not be dissipated by any of the older counter-recoil devices when firing at the latter or even the medium degrees of elevation. One solution of this problem comprises a check of a sort on the recuperator. When the gun recoils the air pressure in the recuperator builds up considerably, and the above solution of the problem comprises the inclusion of a poppet valve in a diaphragm of the air reservoir of the recuperator. As the air pressure builds up, the air opens this poppet valve and passes to the rear portion of the reservoir. As soon as the recoil stops, the poppet valve closes and the air passes from the rear chamber of the reservoir into the forward chamber only through a special orifice that is so small as to keep the air pressure and the pull on the gun within reasonable limits as the gun returns to bat-

tery. This may be an entirely satisfactory solution. It is at least the solution on those 16-inch guns and cradles, or slides, which will be used on some of these carriages as a result of the stopping of our shipbuilding program.

260. The buffer provided in the cylinder, as shown on Plate 123, comprises an extra bronze piston with a number of orifices through it and a sliding valve which can close the orifices through this piston. As the gun recoils the oil between the recoil and buffer pistons passes easily through the orifices in the buffer piston and probably there is little tendency to retard the motion of the gun to the rear. As soon as the pull of the recuperator starts the gun forward, the floating valve at once slides to the rear closing the orifices through the piston and compelling the oil to pass through very much smaller orifices in the valve. This mechanism has worked most satisfactorily. There seems to be no more tendency whatsoever for the gun to charge into battery, even at the extreme angle of depression. It has worked with equal satisfaction at the maximum angle of elevation, that is, +65 degrees.

261. *Recuperator mechanism A.*—Two recuperator cylinders are provided in the complete recuperator mechanism, Plate 125. This recuperator is of a type that has been purchased from the French St. Chamond Ordnance Co. and comprises an air reservoir, cylinder, hollow piston, and a floating piston. The one-piece air reservoir and cylinder is attached to the cradle in brackets or lugs provided for it. The remainder of the mechanism is attached to the recoil band of the gun through a yoke on the front end of the hollow piston and to rods passing to the rear. The hollow piston passes through a most carefully made stuffing box which must prevent the escape of the oil contained between the floating and hollow pistons. Within the hollow piston is a piston rod, at the rear end of which is attached an elaborately made floating piston comprising a bronze piston, several U leathers, an expanding disk, and a spring which continually exerts force on the expanding disk to press the leathers against the walls of the cylinder. The space between the floating piston and the hollow piston is filled with oil, and a special connection will be observed on the top of the air cylinder near the stuffing box through which oil may be forced into the oil space by means of a pump when a certain amount has leaked out. Another stuffing box is provided at the forward end of the hollow piston and this is likewise most carefully made to prevent the escape of the oil past the small piston rod. The yoke just mentioned is attached to the forward end of the hollow piston and the connecting rods are attached to it on either side. Special guides are provided for the forward ends of these connecting rods, thereby serving to keep in place or to center perfectly the hollow

piston, which has no other support. The two connecting rods pass to the rear and are attached by nuts to the recoil band.

262. When the gun recoils, the pull on the connecting rods forces the yoke and hollow piston to the rear. The motion of the hollow piston to the rear is communicated through the pressure on the oil to the floating piston, which moves to the rear at the same rate. The initial pressure of air carried to the rear of the floating piston is approximately 1,770 pounds per square inch. This builds up to approximately 3,140 pounds at maximum recoil. It is fairly safe to assume that there is no difficulty from the escape of air; although some air might pass the floating piston, it must likewise pass the recoil piston. The net result is that the air pressure simply serves to push the floating piston forward with a certain pressure. This results in a tendency of the oil to gradually escape through the two stuffing boxes; and it does escape through both, though very slowly. As the oil leaks out, the floating piston is forced forward, and when the graduated forward end of the front piston rod projects a certain extent those in charge of the maintenance of the carriage simply pump in more oil by means of the refilling pump that is provided. Two recuperator cylinders have been provided in this case, not because it was felt necessary to divide or balance the recuperating pull but because it would have been necessary to use either an excessive air pressure in a single small recuperator or provide an excessively large recuperator for use with normal air pressure. This is the type of recuperator that has been used with the 12-inch mortar on its railway carriage, the 12-inch howitzer also on a railway carriage, the 16-inch howitzer on its barbette carriage, and it is being incorporated in the 14-inch railway carriage, model 1920. This same type of mechanism is used in the French 340-millimeter gun, 400 and 520 millimeter howitzers, all on railway mounts, with entire satisfaction, and has been given such a try out as to prove it entirely satisfactory for heavy guns. Its first use in the American Army was with the 12-inch mortars mounted on railway carriages for service in the World War. It proved so satisfactory and pleasing a design as to commend it for universal use.

263. *Elevating mechanism A.*—The elevating mechanism, Plate 135, comprises the antifriction mechanism incorporated in the trunnion bearings, Plate 137, two racks mounted on either side of the cradle with trains of gears leading to the handwheel, speed gear and motor on the right side of the carriage. A buffer incorporated in each side frame is provided for stopping the gun without serious jarring at either extreme of elevating, Plate 138, and a friction brake operating through a hand lever mounted on the right side of the carriage, Plate 136.

264. The antifriction mechanism used on this carriage is to a certain extent unique in that it includes a roller bearing not used on carriages previously built by us at least, although similar rollers were in use during the World War on French 320 railway mounts. This mechanism, Plate 137, comprises the main trunnion of the gun, the end of which is recessed and is fitted with a smaller bearing pin. It comprises also the nest of rollers between two collars or bearings, the inner of which fits over the bearing pin already mentioned and rotates with the gun, while the outer rests on the bearing post and is stationary. The bearing post passes through a vertical hole in the trunnion bearing of the side frame and is supported on the beam, the lower front end of which rests on and may rotate about a steel pin and the rear end of which is supported through a steel rod on three pairs of Belleville springs. When the gun is assembled in the carriage the main trunnions, of course, bear upon the main trunnion bearings, and the friction is very great. If no provision were made for reducing this friction, it would be impossible to elevate the gun except at an exceedingly slow rate through a very great reduction in the gearing. When the gun and antifriction mechanism have been assembled the rear end of the supporting beam is drawn up by means of the two nuts C and D until it is possible to insert a 0.02 feeler gage between the main trunnion and the main trunnion bearing. The gun is then being supported on the rollers. The main trunnion is practically floating with reference to its bearing. The coefficient of friction when the bearing is properly adjusted is 0.0015 and relatively little effort is required on the elevating handwheel to raise or depress the gun. Interesting data with reference to a test of this roller bearing is given in the table in paragraph 277.

265. The circular spur gear racks are attached on either side of the cradle toward the rear and mesh with identical pinions which, on the right side, lead through spur gears and various clutches to a fast motion crank, slow-motion handwheel, speed gear, and power motor; on the left through a similar train of spur gears to a hand crank only. The elevating mechanism units on both side of the carriage are equipped with friction band brakes the control levers of which are both located adjacent to the handwheel on the right side only. It is pertinent to note here the use of spur gears only in this elevating mechanism. Before the World War it was common practice to include a worm wheel and worm in most elevating mechanisms. These introduced a considerable amount of friction, thereby increasing the effort required to elevate and depress the gun, and their use has been discontinued since they have been found not at all necessary. The friction drum and band of the brakes mentioned above are included on the shaft of one of the gears of the train

to serve as a sort of slip-friction device and prevent excessive loads coming upon the gears in firing. Normally the gun will not be elevated or depressed by hand but by the electric motor through the Waterbury speed gear, which controls most satisfactorily the rate of elevation between very wide limits. Through the use of this gear it is possible to elevate or depress the gun in approximately 10 seconds. It is possible also to reduce the rate of elevation through this gear to such a point as to permit of final fine laying of the gun on the target. The ratio of motion of the handwheel to motion of the gun is one revolution of the handwheel per degree of elevation.

266. In designing this elevating mechanism, as explained in Part II, it was found that the gun could be so balanced as to give a certain muzzle preponderance when empty and a certain breech preponderance when loaded. Thus, as soon as the gun has been fired, after the brake band is released through pulling up of the brake lever and a spin given the handwheel, the gun will drop smoothly to its loading position in approximately 10 seconds. As soon as the gun is loaded, after the brake band is released and the handwheel given a spin, the gun will rise to any desired approximate elevation. It is probable that little can be gained by this method of elevating and depressing over operation by means of the motor; but in the event of difficulties with the motor and its possible failure, the gun can be operated almost as rapidly by hand, so far as elevating and depressing is concerned, as by power.

267. Since there is a possibility in the scheme of automatic elevating and depressing just described, as well as in elevating and depressing by power, of the gun reaching its limit before the power is turned off or the brake applied, it was thought desirable to provide some sort of a buffer that would prevent injury to the mechanism. This mechanism, Plate 138, comprises a lever rotating about a pin in the side of the carriage, the one end of the lever coming in contact with a stop on the elevating rack and the other end engaging in a slide on the end of two spring rods. The springs used in this case are Belleville washers, because this is the only type of spring that is sufficiently strong to serve satisfactorily under the forces applied. When the stop on the elevating rack strikes the one end of the lever the other end forces the slide down against the springs, and although the motion is ever so slight it is sufficient to reduce the stresses in the various parts of the elevating mechanism and in the carriage likewise to within reasonable and safe limits.

268. *Traversing mechanism A.*—The traversing mechanism, Plate 146, comprising a ring of 44 conical rollers, bearings on the base ring and racer, a traversing rack made in 12 sections and bolted to the base ring, a train of bevel and spur gears leading directly to the slow and high speed handwheels and cranks and through the speed

gear to the electric motor. In this mechanism, as well as in the elevating mechanism just described, worms and worm wheels have been eliminated because of the excessive friction that they involve. The load on the handwheel required to traverse this mechanism does not exceed 30 pounds, and the ratio of the gearing for the rapid mechanism is 1 turn of the crank for 1°, while the ratio of the slow mechanism is 10 turns of the handwheel for 1°. In normal service it is expected that the gun will be traversed by a special azimuth observer located in a cab below the floor, Plate 149. A circle on the base ring is graduated to degrees and a vernier, Plate 150, is provided on the indicator which rotates with the racer and reads to hundredths of a degree. The azimuth observer is provided with head phones and receives his instructions directly from the plotting room. This provision is unlike that of any other carriages previously built and seems superior to the scheme requiring one observer to lie flat on the floor observing a graduated ring through a trapdoor while another operator a short distance away rotates the carriage through a handwheel. On Plate 148 the clutch which engages the hand-operating mechanism is shown. It is seen here that unless the foot pedal is pressed, thereby forcing the clutch, which is keyed to the shaft, to engage with the bevel gear on the crank shaft, neither the slow-motion mechanism nor the crank have any positive connection that will rotate the carriage. When the foot is off the pedal it is possible to rotate the carriage only by means of the electric motor through the speed gear.

269. *Loading mechanism A.*—On all other carriages, with the exceptions noted below, hand or gravity loading has been used; because, in some cases, the weight of the projectile did not justify the use of the more elaborate power mechanism, and in others, such as the disappearing carriages firing shells of the same weight as used in the gun under discussion, the momentum of the shell as delivered with considerable velocity in the shot truck to the breech of the gun greatly lessened the effort required to ram by hand. In this mount, however, the following conditions were large factors in deciding that power ramming and the scheme as adopted for ammunition supply was practically essential if we were to attain the speed desired, viz, a method of loading with the gun set to a slightly elevated position, finally decided at +4 degrees, thereby saving 8 degrees of movement over guns that load at horizontal; an arrangement that will supply ammunition to the gun continuously and at any point in the traversing cycle, thus eliminating the necessity of bringing the carriage to any fixed position in azimuth or even of stopping the traversing movement as when following a moving target. In the event of the failure of power supply, the mechanical efficiency of the chain rammer when operated by hand cranks would

give it preference over the other types of loading mechanisms in view of obtaining the above-stated results.

270. The combination of mechanisms, cars, trackage, and so forth, that comprises this loading arrangement was originally peculiar to this mount, but later adapted to the 16-inch howitzer and, in part, to the 14-inch railway mount emplacements. Starting at the magazine, the sequence of operations for loading is as follows: The shell and powder cars, Plates 156 and 157, respectively, are loaded on their track in the magazine, each with 3 rounds, the powder charge consisting of 4 sections per round or 12 sections per car. A gasoline engine truck on railway wheels is employed to push the two cars out of the magazine and up to the circular track surrounding the mount. Here the truck is uncoupled and returned to the magazine while the cars are shunted by hand power to their respective positions at the rear of the mount, where they are made fast to and travel with the traversing parts until their ammunition supply has been discharged, after which they are unlocked and run back to the magazine for reloading.

271. Observance of Plate 156 will show a runway platform on each side of the shell car, which is folded up vertically in transit, thus forming a chock or barrier for the shells. When latched to the mount the runway on the near side is swung down horizontally until the end rests on and is flush with the shell turntable of the mount at the right side of the rammer. Onto this table from the car, by means of the runway, the three shells are rolled and on coming to a rest on the table are in a position of about 45 degrees with respect to the rammer. The turntable is then revolved until the shells point forward and parallel to the gun, after which they are rolled to the left onto and over the parking platform until the foremost shell drops into the trough of the tray ahead of the rammer. These operations can easily be followed by inspecting Plate 155. It is possible with this scheme of loading to have six shells on the mount proper at one time besides the three on the attached car ready for unloading when space on the turntable and parking platform permits. It should also be understood that any or all of these operations, as well as the powder operations described below, can be executed while the mount is under traversing motion.

272. Unlike the projectiles, the powder sections are not exposed on a parking platform any longer than is necessary to slide them from the car to their position in front of the rammer. On Plate 157 it will be seen that in designing the powder car care has been taken to protect its cargo from undue exposure to temperature change or dampness. The car is housed over, sides and top, and the trays fold up to form the ends in transit. The tray adjacent to the mount, like the shell car, is swung down and rests on the powder

platform to the left of the rammer, and, as the powder is required for loading, the hand-operated chain conveyer in the car is used to deposit two sections of powder in the trough of the tray in a position parallel to the rammer. A hand staff rammer is used to slide this half charge forward onto the powder platform until it is in a position to be rolled to the right into the trough ahead of the rammer. The remaining two sections of the charge follow immediately and are ready to be rolled into the rammer trough by the time the rammer is withdrawn from loading the first sections.

273. The power chain rammer is a new departure in the loading scheme of barbette carriages, but rammers of this type have been in use in naval and Army turrets for a number of years. The rammer in this mount, Plate 158, comprises a cast-steel frame or housing and a flexible forged steel chain, the latter being driven through sprockets and gearing by a speed gear and motor. Facilities for using hand cranks, in event of power trouble, are also provided.

274. The spanning tray is unusual inasmuch as it is supported in a spring-balanced position over the rammer frame during recoil of the gun and can easily be launched to the front and downward to its loading position between the rammer head and the breech opening. A rather unique feature of the breech platform is due to the fact that it does not swing back to clear the recoil of the gun but is attached by means of cantilever beams to the under side of the cradle. These beams, with the platform across their rear end, are sufficiently low to permit the gun and band to recoil over them and, being a unit with the cradle, elevate and depress with the tipping parts.

275. *Top carriage A.*—While the term "top carriage" applies to no well-defined group of parts of a barbette type of mount, it may be assumed, however, to include those parts of the carriage above the traversing rollers that have not been described as a special mechanism in the previous paragraphs. With this assumption in view, it may be said that the top carriage of this mount comprises the two cast-steel side frames, Plate 132, placed parallel and with both ends keyed and bolted to the top surface of the racer. The racer is of cast steel and consists of four sections, butted and bolted, forming a complete ring resting on the traversing rollers and located by its pintle extending into the base ring. Equally spaced along the under side of each side frame are three cast-steel floor beams that extend outward to the racer and are bolted to the inner vertical surface of it. These form a lateral bracing for the side frame, stiffen the racer as a ring, and are the main support of the flooring. Against the outside vertical surface of the racer a number of cast-steel brackets are bolted and support the circular platform that surrounds the entire mount. When assembled in place this platform bridges

the gap between the floor of the mount and the concrete surface of the emplacement. The vertical force of firing is taken directly by the rollers, while horizontally the top carriage is held by the pintle mentioned above. Any tendency of the mount to overturn when firing at low angles is checked by a number of cast-steel clips attached to the racer, front and rear, and hooking under a projecting ledge around the base ring.

276. *Base*—A.—The base, Plate 152, is made up of four sections sufficiently rigid when finally bolted together to provide a perfect bearing for the 44 conical rollers on which the top carriage is supported. This bearing carries around its top and outer edge the traversing rack made up in 12 sections, and it is machined to a cone within for the roller bearing. Just under the traversing rack an azimuth ring is provided which is graduated to degrees after the mount has been emplaced. As mounted in the coast fortifications this base rests on a concrete foundation, and the azimuth ring is graduated so that wherever the azimuth observer's cab may finally be located his indicator is at zero azimuth when the gun is pointing due south. This practice of causing the direction of due south to be known as zero makes it necessary to leave the graduating of the azimuth ring until the carriage has been emplaced.

277. Following is a tabulation of miscellaneous data with reference to this gun and carriage:

Weights and capacities.

Gun, wire-wound, approximately 70 feet over all:

Weight of gun and breech mechanism with recoil band filled with lead ---------- pounds--	385, 847
Weight of gun ---------- do----	326, 624
Weight of recoiling parts ---------- do----	399, 917
Weight of tipping parts ---------- do----	499, 200
Weight of projectile ---------- do----	2, 340
Weight of powder charge ---------- do----	850
Total weight of tipping parts, not including gun and band---do----	113, 353
Total dead weight that comes on foundation ---------- do----	1, 000, 000
Total piston-rod pull fired at 65° elevation ---------- do----	1, 642, 686
Total weight of the cradle itself, machine finished, and all surfaces requiring same, including caps holding recuperator cylinders to the cradle ---------- pounds--	75, 420
Weights of principal castings as delivered from the foundry (no machining):	
Bast ring, 4 sections, each section ---------- tons--	21
Racer, 4 sections, each section ---------- do----	25
Distance rings, 6 sections, each section ---------- do----	1. 05
Cradle ---------- do----	51
Side frames (2), each ---------- do----	17
Capacity of recoil cylinder, long ---------- gallons--	38. 5
Capacity of recoil cylinder, short ---------- do----	17. 5

Test to ascertain whether the tipping parts are floating perfectly: *Disconnect the pinion from the elevating rack, load the gun with shot and full charge, and hang a weight of 146.5 pounds at the muzzle. This will give perfect equilibrium. Then apply at the muzzle either up or down an effort equal to 60 pounds.*

Test for adjustment of trunnion when floating completely by thickness gauge: Left trunnion, .037; right trunnion, .036.

Load required at slow-motion handwheel in elevating should not exceed 17 pounds.

Time to elevate the gun from 0 degree to 65 degrees, using slow-motion handwheel, should not exceed 27 seconds.

Test of cradle trunnion roller bearings: 800,000 pounds.

Scleroscope hardness of rollers: 100.

Scleroscope hardness of inner and outer sleeves: 96 to 100.

Test pressure of the long recoil cylinder, per square inch: 7,050 pounds.

Test pressure of the short recoil cylinder, per square inch: 7,050 pounds.

Test piston rod pull (short): 596,740 pounds.

Test piston rod pull (long): 596,740 pounds.

Test for strength of recoil cylinders under hydraulic pressure, per square inch for 15 minutes: 4,250 pounds.

Test for air leakage under air pressure per square inch: 3,550 pounds.

Fittings of expansion chamber for recoil cylinder were tested with working oil pressure of 500 pounds per square inch and oil test pressure of 1,000 pounds per square inch. The capacity is 3.73 gallons.

Force required to pull the gun into recoiled position against the compressed air in the recuperator system: 800,000 pounds.

The retracting device, which is rather unique in that all corrections can be made in the shops instead of firing and dismantling the carriage as was previously done, consists of a hydraulic cylinder which was screwed into the breech bushing thread of the gun, the cylinder extending into the powder chamber. A stationary beam was mounted on two steel tubular columns which was securely screwed to the rear ends of the recuperator cylinders. The piston rod of the pull back cylinders was passed through a hole in this stationary beam and secured to it by means of a steel strap and key. Water was pumped into the pull-back cylinder through a hole in the piston rod to retract the gun. The stationary beam being connected to the cradle remained fixed, while the pressure of the water on the cylinder head forced the gun back against the pull of the

recuperator cylinders. When the gun had been moved to the rear, the position corresponding to the normal recoil, the straps were cut by means of a torch allowing the gun to return to battery, Plates 133 and 134.

The force exerted on the beam to retract the gun at 0 degree elevation, with a pressure of 5,000 pounds per square inch in the air cylinders, was 828,000 pounds. The device was used for snapping the gun at 0 degree, 34 degrees, and 65 degrees, and functioned satisfactorily.

FORCES—STATICS—RATIOS.

The center of gravity of the recoiling parts is 224.705 inches from the breech face of the gun.

The center of gravity of the gun, including the breech mechanism with lead filled band, is 228 883 inches from the breech face of the gun.

A movement of 1.74 inches forward and 1.625 inches rearward has been provided for balancing.

The carriage is designed to permit firing at minus 7 degrees and plus 65 degrees.

The following forces are required to retract the gun when the initial air pressure is 1,770 pounds: —7 degrees, 720,000 pounds; 0 degree, 672,000 pounds; +65 degrees, 283,000 pounds.

The normal recoil is 40 inches; maximum, 42 inches.

Normal pressure of air in the recuperator: Initial, 1,770 pounds per square inch; final, 3,140 pounds per square inch.

Normal pressure of liquid in recuperators: Initial, 1,950 pounds per square inch; final, 3,450 pounds per square inch.

Dead load on each crutch of antifriction mechanism: 247,000 pounds.

Initial load on each spring column: 22,300 pounds.

Ratio of arms of levers: 12 to 1.

Belleville springs in traversing gear friction box: Load at assembled height, 10,000 pounds.

Elevating gear ratio, left side: One turn of crank counterclockwise elevates gun 3 degrees 20.5 minutes.

Elevating gear ratio, right side: One turn of handwheel counterclockwise elevates gun 1 degree 4 minutes.

Pressure capacity of liquid pump: 2,500 pounds per square inch.

Blow off pressure of liquid pump: 2,200 to 2,500 pounds per square inch.

MISCELLANEOUS.

Electric traversing motor: General Electric Co. type CBC–47 motor, totally inclosed. Waterproof, shunt wound with commu-

tating fields, 7½ horsepower, 500 revolutions per minute, constant speed, nonreverse. Designed for use with 110-volt direct-current circuits.

Hydraulic traversing speed gear: Waterbury Tool Co. Size 5; type C. The approximate weight is 180 pounds. The control shaft makes .781 turns from 0 to full speed either direction, clockwise for traversing muzzle right. The capacity is 27 horsepower at 675 revolutions per minute with oil pressure 800 pounds per square inch. The capacity required to traverse 118 degrees 47 minutes in one minute or 500 revolutions per minute at the "B" end with the oil pressure at 86 pounds per square inch is 2.25 horsepower at the "B" end and 2.75 horsepower required of motor.

Elevating motor specifications: General Electr'c Co. type CBC–46 motor. Frame No. 10. Motor totally inclosed. Waterproof, shunt wound with commutating field, 50 horsepower, 400 revolutions per minute, constant speed, nonreversing. Designed for use with 110-volt direct-current circuits.

Hydraulic elevating speed gear: Size, 35 type. Special right angle V. P. with follow-up control. Waterbury Tool Co. drawings 13186 and 13187.

Air compressor; specifications: General Electric Co. type 33; 2-stage, single-acting, duplex air compressor. Direct connected to General Electric Co.'s type CBC–45 motor. Frame No. 7. Motor totally inclosed, waterproof, series wound with commutator field, 30 horsepower, 800 revolutions per minute, rated speed, non-reversing. Designed for use with 110-volt, direct-current circuits. Air compressor to have a displacement of approximately 102.7 cubic feet free air per minute and actual delivery of approximately 80 cubic feet free air per minute. Operating at working pressure of 150 pounds per square inch the set is capable of operating for one hour continuously out of two hours—that is, for one-half time operation. Total net weight of approximately 4,200 pounds.

Power cables: Leaded and armored type, armature —1, armature —2, 250,000 c. m. area single-conductor cables.

Drum controller for elevating motor: 7½ horsepower controller. The controller is used to energize solenoid of contactors.

Control panel and inclosed rheostat, elevating: General Electric Co. type CR–5582 or equal. Panel designed to suit requirements of 50-horsepower motor used for elevating. Average current for which resistor is designed does not exceed 150 amperes. Data for power cable: Main L_1, L_2; armature A_1, A_2: 400,000 c. m. area single-conductor cable. Rheostat R_1, R_2, R_3, R_4: 150,000 c. m. area single-conductor cables. Shunt field F: 4,000 c. m. area single-conductor cable. Control C_1, C_2, C_3, C_4: 4,000 c. m. area twin-conductor cables.

Controller rheostat panel, traversing: 61-ampere, 110-volt, 7½-horsepower motor for rammer: General Electric Co. type CBC–45 motor. Frame No. 7. Motor totally inclosed. Waterproof, shunt wound with commutating fields, 30 horsepower, 500 revolutions per minute constant speed, nonreversing, 110-volt direct-current circuits. Specifications demanded efficiency of motor at its rated load to be not less than 85 per cent. Power cables, leaded and armored type: Armature A–1, A–2: 25,000 c. m. area single-conductor cables. Shunt field F–1: 4,000 c. m. area single-conductor cables. Drum controller for rammer; motor equipment: General Electric type R–191–B duty. Used to start and stop the rammer motor (rated 30 horsepower at 500 revolutions per minute.) starting duty being to bring the armature shaft and the "A" end of size No. 10, type K, hydraulic speed gear up to full speed under light load conditions, with the control shaft of speed gear in its neutral condition. Load current of motor not carried through drum controller.

Power cable: Leaded and armored type. Rheostat R_1, R_2, R_3, R_4; 150,000 c. m. area single-conductor cables.

Cables C_1, C_2, C_3, C_4: 4,000 c. m. area twin-conductor cables.

Control panel, inclosed rheostat, rammer: General Electric Co. type CR–5582. Designed to meet requirements of rammer motor.

Power cables: Leaded and armored type. Main L_1, L_2,; armature A_1, A_2: 250,000 c. m. area single-conductor cables. Shunt field F_1: 4,000 c. m. area single-conductor cables. Control C_1, C_2, C_3, C_4: 4,000 c. m. area.

The average starting current for which resistor is designed is 150 amperes.

2. 16-INCH 50-CALIBER RIFLE ON DISAPPEARING CARRIAGE, MODEL OF 1917.

278. *Cannon B.*—The cannon used on this carriage is identical in its essential features to the cannon described under A, paragraph 252. Since this carriage is of the disappearing type it has not been practicable to employ the drop type of breech; hence the gun differs from A in the provision of the hinge on the breech face, which, through a hinge pin, carries the tray on which the block may be drawn to the rear and swung to the side. An additional difference is the omission of the gas ejector.

279. *Breech mechanism B.*—This mechanism, Plate 164, differs from A, paragraph 253, in that it comprises a hinge screwed to the breech face of the gun and a tray swung about the pin through the hinge, thereby making it possible to swing the block to the side instead of down, as with the barbette carriage. The principal parts of this mechanism comprise the hinge, hinge pin, operating crank,

operating worm, worm wheel, tray, tray latch, tray-latch catch, compound gear, and breechblock.

280. The hinge is secured on the breech face of the gun by means of seven large screws. It possesses two lugs bored for the reception of the hinge pin. At its extreme lower end it has an additional lug bored out for the reception of the operating worm. The hinge, in addition, serves the purpose of preventing the rotation of the breech bushing in its seat. The hinge pin fits in the lugs of the hinge, being supported on the upper lug by a collar which is a part of the hinge pin. To it are attached the compound gear and the worm wheel, and between the two hinge-pin lugs is the tray. The tray is not fixed to the hinge pin, but revolves about it. The hinge pin is grooved for the purpose of permitting a flow of oil to the different parts.

281. The operating crank is secured to the worm on its squared end and held there by means of a set screw. The operating worm is set in the lower hub on the hinge. It has two ball-bearing washers, one on each side of the worm, secured by a threaded housing. These bearings reduce the friction due to the thrust when the worm engages the worm wheel. The worm wheel is secured to the hinge pin by being fitted on its squared end. It is held in place on the hinge pin by a nut, and this nut is pinned to the hinge pin to prevent its backing off.

282. The tray is suspended on the upper surface of the lower hinge lug and held in position by the hinge pin passing through the two hinge lugs. The compound gear is assembled directly beneath the upper lug and rests on the top of the tray. This gear is secured by means of two keys to the hinge pin. There is a ball-bearing washer between the upper part of the lower hinge lug and the lower edge of the tray to permit easy rotation. The tray is profiled to fit corresponding profiles in the lower part of the block. The tray is held to the face of the gun when in that position by means of a tray latch, which fits in the tray-latch catch, the latter being secured in the milled recess on the face of the gun and held by means of two screws.

283. The tray-latch catch has a plunger set in it actuated by a spring. This plunger is called the tray-latch plunger. The tray latch has a plunger passing through it which is called the tray-latch operating stud. To the rear of the tray latch setting in the tray is located the tray-latch lock bolt, actuated by a spring. The tray latch is suspended from the tray by means of a tray-latch pivot which passes through it. The tray-latch lock bolt prevents the latch from rotating or tipping by entering a hole in the latch, which hole is the seat for the tray-latch operating stud when the latter is forward. The action of the tray latch is as follows: When the tray is closed against the face of the gun the operating stud passing through the latch

is forced to the rear by its forward end striking the face of the gun. This forces out of the seat in the latch the tray-latch lock bolt. The latch striking the tray-latch plunger located in the tray-latch catch tips the latch so that its forward end is on a level with the tray, the lower forward point of the latch engaging its seat in the catch. The block is then free to go forward. These movements are, of course, automatic and occur when the block on its tray is swung around for entering the breech recess. On the bottom of the block is a rectangular milled-out recess in which a rectangular web is left. The rectangular web thus left in the bottom of the block fits into a corresponding recess on the top of the tray latch. When the block is withdrawn this web comes into contact with the latch, tipping it and unlocking the tray from the face of the gun. At the same time the rectangular recess in the upper part of the latch engages in the rectangular web on the block, thus locking the tray to the block. In this position of the latch the tray-latch operating stud goes forward and allows the tray-latch lock bolt to engage in the latch, preventing any tipping. When the tray is closed the operation is the reverse. The tray-latch operating stud is forced back, thus forcing out of its recess the lock bolt. The latch is tipped by the tray-latch plunger, the tipping causing the latch and the catch to engage. The web on the breechblock being free, the block is permitted to go forward.

284. The compound gear is attached to the hinge pin by means of two keys. About one-half of this gear is cut spiral and the other half cut spur. The spiral part engages in the spiral rack cut on the breechblock and causes the block to revolve. The spur part engages the translating rack cut on the breechblock and is used for translating the block in and out. The spiral part of the gear is of less diameter than the spur, so that more clearance is given to the loading of the projectile as that part comes in line with the bore when the block is opened ready for loading.

285. The breechblock has a ratchet form of tooth rounded at top and bottom. It is of the Wellin type or step type, divided up into 12 sectors, 9 of which are threaded and 3 unthreaded. It thus only requires 30° of rotation to disengage the threads on the block from those located in the thread box or breech bushing. On the breechblock is machined the spiral rack for rotation and the spur rack for translation. The spindle, filling-in disk, and split rings are similar in construction to other large-caliber guns. Both of the large split rings are centered by means of shoulders to the obturator spindle and the filling-in disk. This is for the purpose of preventing sagging of these parts.

286. This mechanism functions by a continuous movement of the operating crank. To open the gun the crank is turned to the right

a total of 9.90 turns, of which amount 2.79 are necessary to rotate, 4.22 are for translating, and 2.89 to swing the block clear. In closing, the reverse is the case. Individual description of the functioning of each of the parts composing the breach mechanism during the operating is unnecessary, as the description given of these individual parts plainly shows how they function during their active operations. The rotation of the block in closing is limited by a filler or strip attached to the side of one of the threaded sectors, which comes into contact with the side of its adjoining sector.

287. *Firing mechanism B.*—The principal parts of this firing mechanism, comprise a hinged collar, housing, slide, and firing leaf. The hinged collar embraces the rear end of the spindle, two ribs on its inner surface engaging in corresponding grooves in the spindle. The housing screws over the hinged collar, which is threaded to receive it, and a spring catch locks the collar to the housing when it is fully screwed home. The collar is thus prevented from opening and secures the housing to the spindle. A guide bar projects from the right side of the housing into a longitudinal groove cut in the block recess and causes the housing to rotate with the block. The slide travels vertically in grooves cut in rear face of the housing and when in its lowest position holds the primer to place in the primer csat. Its motion is limited by the slide stop on the left side of the housing. The slide catch serves to lock it to place when lowered, and to support it at the proper height to allow the primer to be inserted when raised.

288. The ejector is an L-shaped piece with trunnions at its angle, about which it swings, and which enter two slots cut for them in the housing. The lower arm of this extractor is fork shaped and hangs over the mouth of the primer seat under the head of the primer. The horizontal arm projets to the rear into a recess in the slide, and when the later is lifted this arm is carried upward and the ejector rotated about its trunnions so as to throw the horizontal arm to the rear, ejecting the primer.

289. The firing leaf is pivoted to the slide at its upper end. It has a vertical slot cut in its lower edge through which the wire of the primer projects when the slide is in its lower or locked position. At the right-hand corner of the leaf is an eye into which the lanyard is hooked for friction firing. When the leaf is drawn to the rear it engages the button on the end of the primer wire, draws the wire out, and fires the primer frictionally.

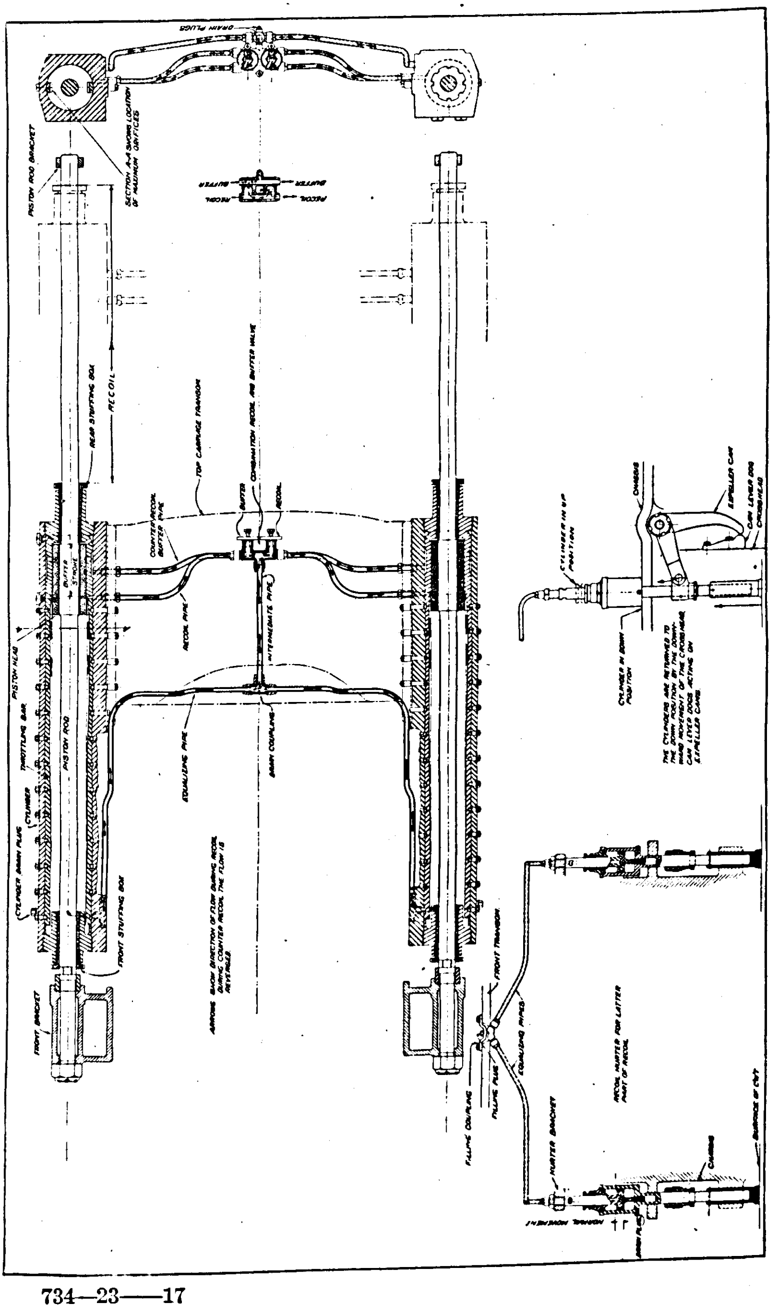
290. Electric connection with the primer is made through the arms of the contact clip, which embrace the head of the primer. The contact clip is secured to the rear face of the leaf. The electric cable terminal is made of a piece of copper thimble flattened at one

end, the flattened portion being provided with a hole for the reception of the contact clip plug. The terminal is attached to the firing cable by passing the wires of the cable through the thimble and spreading the wires into notches cut into the terminal and then soldering. The terminal is attached to the contact clip by means of the contact-clip plug. The other end of the cable is fitted with the circuit-breaker contact pin. This is attached to the firing cable by stripping the insulation from the cable, passing the wires up into the pin and dropping solder into holes provided therein for soldering the contact pin to the cable. In order to prevent possible short circuiting between the primer body and the firing leaf, the contact-clip nut should be tightly set up. A safety bar prevents accidental firing of the piece by lanyard before the breech is locked, and a circuit breaker serves to prevent firing the piece by electricity before the breech is locked.

291. The first motion of rotation of the block to unlock the breech forces the safety bar inward so as to engage the leaf and to prevent its being drawn to the rear, while at the same time the electric circuit is broken by the same movement of rotation. A safety bar on the right side of the housing engages a groove in the firing leaf and prevents the latter from being drawn to the rear before the breechblock is rotated to its locked position. The last part of the motion of lowering the slide makes electric connection with the primer. It will be seen from this that accidental firing of the piece is impossible until the breech is locked and the slide of the firing mechanism is in its lower or locked position. The circuit breaker is of bronze and consists of two principal pieces, which are brought together when the block is rotated to its locked position. A plunger working under the pressure of a spring serves to make electric contact between the two pieces. Both parts of the circuit breaker are insulated from the piece by vulcanized fiber. The electric cable is attached to the circuit breaker by a spring fork.

292. *Recoil mechanism B.*—The recoil mechanism, Plate 166, comprises the two levers supporting the gun and rotating about an axle on the top carriage containing the recoil cylinders, a carriage containing two recoil cylinders, two sets of recoil rollers supporting this top carriage, a pair of guides on either side of the front of the carriage to guide the lower end of the levers in a vertical plane, a counterweight, and hydraulic hurter cylinders. The top carriage rests on a plane of 1 degree slope and as the gun recoils the carriage moves to the rear a distance of about 90 inches. The one relatively fixed part of this mechanism, so to speak, is the lower end of the levers. These are constrained to move in a vertical plane by the guides already mentioned. As the gun recoils, therefore, the energy of recoil is dissipated in doing the work of forcing the oil through the orifices

PLATE 166.



RECOIL BRAKE MECHANISM OF THE 16-INCH 50-CALIBER GUN DISAPPEARING CARRIAGE.

in the recoil cylinders and in raising the counterweight, which must be drawn upward as the top carriage moves to the rear.

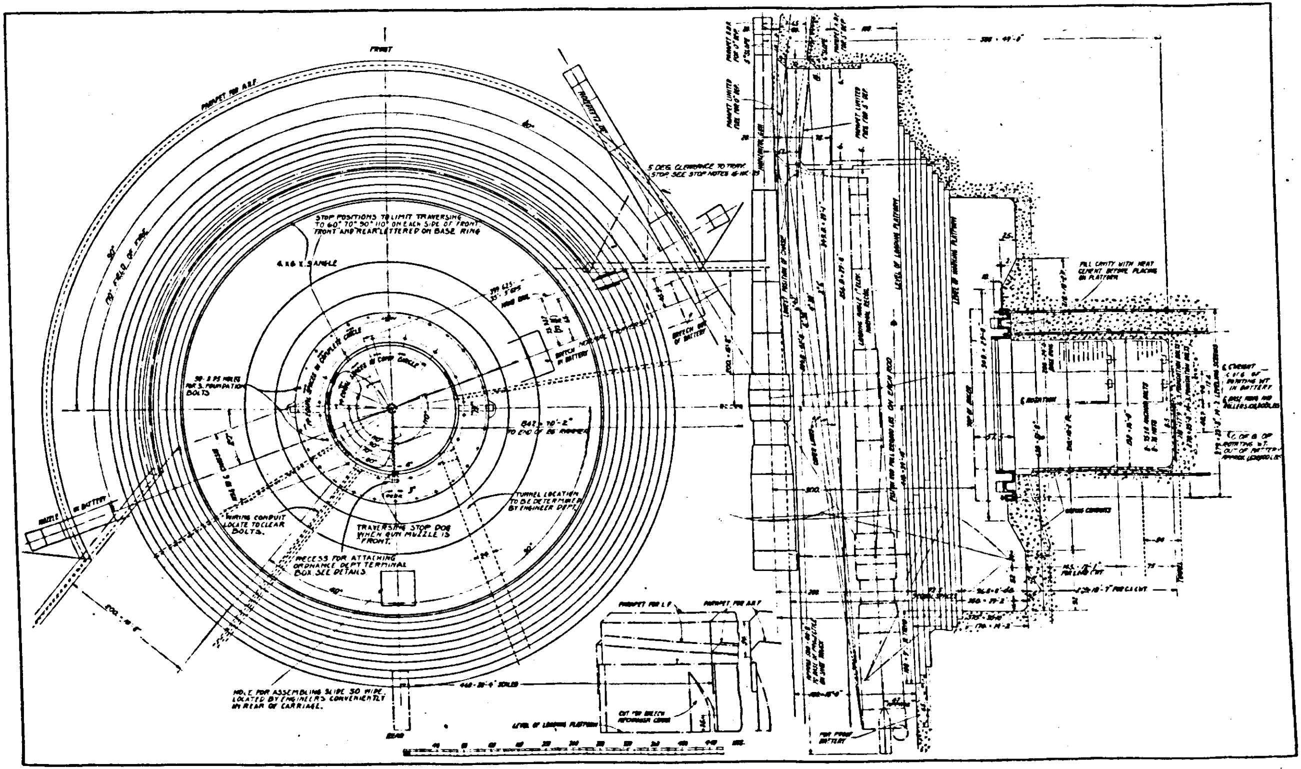
293. The action of the carriage is as follows: Upon firing the piece, the axle of the gun levers, Plate 167, moves to the rear, carrying the top carriage with it; the lower ends of the levers move vertically upward, being constrained by the crosshead guides; the gun moves downward and to the rear, the trunnions describing the arc of an ellipse. The energy of recoil is absorbed partly by raising the counterweight, but principally by the resistance of the hydraulic recoil cylinders. Near the end of recoil the effect of the horizontal cylinder is not appreciable, and at this time the hydraulic hurter cylinders come into action and effect a final stop. When the gun comes to rest it should be at about 1 degree elevation for loading, the counterweight having risen approximately 109.5 inches, Plate 168.

294. After loading, the pawls are tripped and the greater moment of the counterweight raises the gun "in battery," the energy at the end of movement being absorbed by the counter-recoil buffers in the rear cylinder heads. Uniform and exact amount of recoil is obtained by adjusting the recoil valve, and complete counter recoil without shock is obtained by adjusting the buffer valve.

295. This type of carriage, involving the use of a top carriage moving in approximately a horizontal plane and a counterweight moving in a vertical plane, is unique with American disappearing carriages and is generally known as the Buffington-Crozier development. The typical British disappearing carriage, on the contrary, involves the supporting of the gun on two main levers of a somewhat similar character but pivoted at their lower end. A recoil cylinder is then mounted in the body of the carriage and its piston is attached to a cross pin approximately in the center of the levers, and no counterweight of the type shown in this figure is employed.

296. The top carriage consists of two sides of forged steel, united by a cast-steel transom, and having roller paths machined on their under sides. On their upper sides the gun-lever axle is supported in beds lined with bronze, and having axle caps of cast steel. The sides are bored for the recoil cylinders. The recoil rollers, of cast steel, bushed with bronze, are fitted free on pins and held in cages of steel. They rest upon the chassis rail, supporting the top carriage and moving to the rear with it for half the distance in recoil. The second, fourth, and sixth rolls from the front ends of the cages have pinions fitted to them which mesh into racks fitted to the chassis and to the top carriage. The top carriage will thus take the rolls along in recoil, notwithstanding their inertia. When time permits, the top carriage should always be brought fully into battery (against the stops); but, if desired, the gun may be fired when

PLATE 168.



EMPLACEMENT OF 16-INCH DISAPPEARING CARRIAGE, MODEL OF 1917.

The rear holes open into the rear end of the buffer seat, while the forward holes open into the cylinder just forward of the buffer seat, thus permitting a free flow of oil to the rear of the buffer as it is suddenly withdrawn at the beginning of recoil, otherwise a very high pressure would occur in the cylinders. To prevent the oil from flowing out of the buffer through the by-pass valves, when the buffer is acting on counterrecoil, each value is provided with two ball checks.

300. Proof firing has shown that it is still desirable to leave room for free withdrawal of the buffer plungers, and as this void can be left without bad effects the filling holes have been located accordingly. Plugs are provided to close the cylinders, thus continuing the piece in action should the pipes be injured and necessitate removal. For emptying the cylinders, valve plugs are provided in the drain coupling, in the combined recoil and buffer valve, and in the cylinders near the front ends.

301. The action of the recoil cylinders is as follows: In recoil the top carriage is drawn over the pistons. Each piston is slotted on its opposite sides, the throttling bars partially closing these orifices. The sectional areas of the bars are varied from point to point so that the areas of orifice for the flow of the oil vary with the position of the cylinders during recoil in such a manner as to obtain a constant resistance, although the velocity of retarded recoil of the top carriage is variable.

302. As in any hydraulic brake the resistance is greater as the velocity of the recoil is greater and as the area of the orifices for the passage of the oil is less. The desired constant resistance is obtained by increasing the areas of orifice from the beginning of motion to the point of maximum retarded velocity of the top carriage and then decreasing them to practically zero at the end of recoil. The areas of orifice must be calculated for a particular set of conditions, including mean temperature. Variations in these conditions may change the length of recoil of the top carriage, and consequently the height and inclination of the breech of the gun in the loading position. It has therefore been found desirable to provide a throttling valve for varying the resistance of the brake in order that variations in the prescribed length of recoil may be reduced to a minimum.

303. The two levers are made of cast steel connected near their upper ends by a cast-steel yoke firmly bolted in place and at a point a little below their middle by the cast-steel gun-lever axle, which is fastened to the levers by bolts passing through its heavy flanges. The gun levers are supported by this axle, the projecting ends of which serve as trunnions supported by and rotating in the axle beds in the top carriage. The lower end of the levers are attached to a crosshead, which, together with the counterweight, may be consid-

ered a part of the recoil mechanism to the extent that considerable work is required to raise them as the gun recoils. They thus serve to assist the recoil cylinders in bringing the gun to a stop.

304. The upper arms of the levers support the gun, and from their lower ends the counterweight is suspended by crosshead pins. The trunnions beds are provided with cap squares clipped on and secured from lifting off by two studs each, having nuts and check nuts. The caps and beds are lined with bronze half bushings. The crosshead, of cast steel, is connected by pins to the gun levers and from it the counterweight is suspended by four keyed rods. The channels on the sides of the crosshead are lined with bronze and fit over the crosshead guides, bolted to the inside of the chassis. These guides constrain the crosshead to move in a vertical direction. Retracting ratchets are screwed onto the front of the crosshead. Pawl boxes, each containing two pawls, are bolted securely to the front clips and to the chassis. The pawl teeth engaging in the ratchet teeth support the counterweight and prevent the gun from returning into battery after firing.

305. The hydraulic recoil hurters are cylinders arranged on the outside of each chassis, apposite the guides, so as to be driven upward over fixed pistons, thus arresting the last 6.4-inch movement of the counterweight and preventing undue shock at the end of recoil. The cylinders and pistons are of forged steel and are connected across the carriage by an equalizing and filling pipe of seamless-steel tubing, which has a coupling and filling plug near the middle of the front transom. The hurter cylinder is withdrawn from the fixed piston, at the end of movement of the counterweight "in battery," by dogs on the crosshead, acting through cams, rock shafts, and levers connected to the cylinder extensions at a point below the lower flange of chassis. To relieve the stress in these parts the piston in each cylinder is provided with three small valves, which allow passage of oil only during withdrawal of the cylinders. These valves are automatic and have no adjustment.

306. Caps are provided to close the upper ends of the piston rods, thus permitting the piece to be continued in action should the equalizing pipe which passes into the hollow rods be damaged and require removal.

307. *Recuperator mechanism.*—B.—The recuperator of this type of carriage comprises the counterweight, crosshead, levers, top carriage, recoil rollers, and buffers. As soon as the latch which holds the gun in loading position at the end of recoil is tripped, the weight of the counterweight pulling down on the forward end of the levers, which at that time are horizontal, causes the rear end of the levers to rise, and inasmuch as the forward end of the levers can move only in a vertical plane because of the guides, the carriage is drawn for-

ward on the rollers. This is facilitated somewhat by the fact that the carriage is mounted on a 1 degree slope. The gun acquires some little velocity in this return to battery, and hence, nearing the end of its motion, the buffers in the recoil cylinder serve to absorb quickly the energy of counterrecoil, bringing the carriage easily to a stop in battery. Since the axle by which the levers are supported on the top carriage is not in the vertical plane of the crosshead guides by approximately 21 inches, the pull of the counterweight produces always a component tending to hold the gun in its firing position. One point that may well be mentioned here is that when the gun is fired and recoils to the position shown in Plate 166, it is automatically held in this position by a latch until released after the gun is loaded. When the gun is at its rearmost position its breech is in the proper position for loading from the platform of the concrete emplacement.

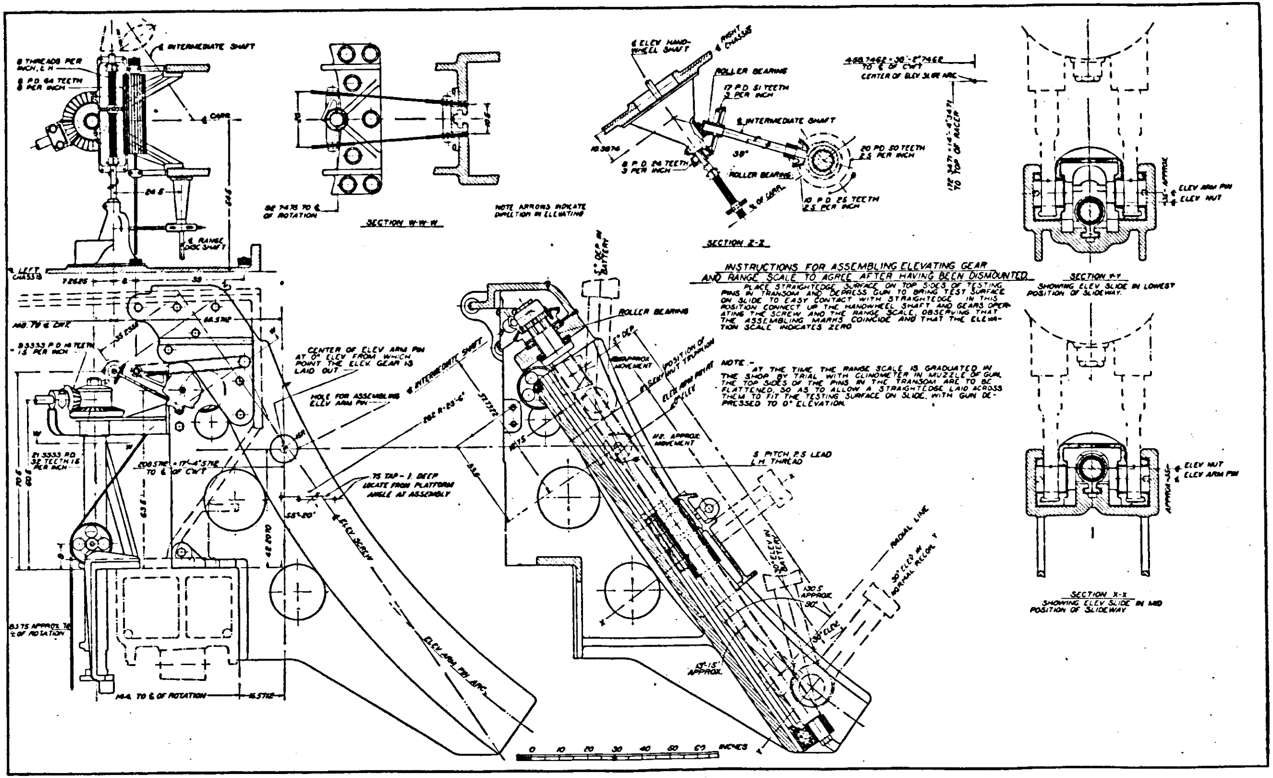
308. After the gun is loaded it is permitted to rise to the firing position by raising the tripping levers until they are latched and immediately leaving them in that position. The tripping mechanism consists of two pawls in a pawl box on each side, supported by the front transom and chassis. The pawls engage rachet teeth on the crosshead, and thus support the unbalanced part of the counterweight when the gun is "out of battery." These are withdrawn by hooks over their top ends, actuated by bell-crank pinions linked up to the cranks on the tripping shaft, which is provided with two levers. The shaft extending across the carriage acts as an equalizer and secures simultaneous action of both sides. The pawls on each side are arranged one above the other and engage alternately; so that, although the pitch of the ratchet teeth is 2 inches, the maximum drop of the counterweight is only 1 inch.

309. When the levers are raised against the stops the bell-crank latches drop behind second arms on the tripping cranks and thus automatically retain the pawl teeth clear of the ratchet teeth until after the crosshead has dropped below the pawls, when the latches are automatically lifted by the cams on the crosshead, thus permitting the levers to drop and the pawls to come out for reengagement. The pawls may be tripped by the use of one or both levers. Two to four men are required to raise the levers. The levers should not be raised while the gun is in battery, but should the pawls become latched out of engagement at this time; the rising of the crosshead will again release them ready for engagement. The pinching-in device consists of two ratchets fitted on top of the front ends of the top carriage, acted upon by multiple pawls hung in a rock shaft arranged on the outer sides of the vertical guides and actuated by two levers permanently attached. In the normal position the levers drop back against stop pins, forcing the pawls against a lifter which carries their points above the rack teeth and clear for recoil.

310. *Elevating mechanism B.*—The elevating mechanism of this type of carriage comprises an elevating arm connecting the band on the breech of the gun with a crosshead mounted on a screw in a special housing on the rear of the chassis. This screw is driven either by hand or an electric motor through a train of spur and bevel gears. When the crosshead is at its lowest position the gun is at its maximum elevation, and when at its highest position the gun is depressed to the maximum. Study of the mechanism on Plate 169 will show that such a gun as this is supported, so to speak, in a quadrilateral, the legs of which are a line connecting the main trunnion on the gun with the trunnion of the elevating arm, the elevating arm, a line from the connection of the elevating arm to the crosshead to the center of the crosshead axle, and the lever. This quadrilateral is not a parallelogram at any time; hence the gun does not maintain a series of positions parallel to each other in recoiling from any given elevation. When the gun is elevated to the maximum extent, which for this mount is 30 degrees, the stress on the elevating arms in firing becomes rather excessive, and it was necessary in this case to incorporate in the elevating arms what is known as a kick-down cylinder. This kick-down cylinder permits the rear of the gun to be depressed slightly when fired, thereby lengthening the period of time during which the stresses in the elevating arm are brought to a maximum and correspondingly reducing these stresses. This elevation of 30 degrees is an improvement over the 20 degrees that was secured through the use likewise of a kick-down cylinder on the top carriage of model 1912 and certainly over the first-designed carriages which were provided with an elevation of only 10 degrees. Experiences of the war showed quite clearly that the elevation of 15 degrees and 20 degrees previously attainable was not by any means sufficient for coast service. The maximum elevation that it has been possible to secure on the disappearing carriage is on the design under discussion. Although we are not by any means certain just what can be accomplished through the provision of an elevation so great as 65 degrees, as on the barbette carriage of model 1920, the provision of such an elevation has not served in any way to limit the design of any other part of the carriage; and a comparison of the disappearing and barbette carriages serves very quickly to bring one to a realization that the disappearing carriage is a much less economical and satisfactory carriage to construct and maintain.

311. The ratio of this elevating mechanism is not so important a matter as with barbette carriages where the gun is loaded by depressing the carriage by means of the elevating mechanism. In this case it is possible to set the elevating mechanism at the desired degree of elevation even while the gun is being loaded. As soon as the gun is loaded and the latch is tripped the gun through the pull of

PLATE 169.



ELEVATING MECHANISM OF THE 1917 MODEL DISAPPEARING CARRIAGE.

the counterweight rises at once to its firing position, which is in accordance with the elevation just set.

312. The elevating arm, of cast steel, carries two fixed double-ended pins at its lower end, rotating in bearings in the elevating slide, and has two bronze bushed bearings at its upper end for the elevating band trunnions. The band is of cast steel, with inserted trunnions screwed to their conical seats. The band is keyed to the gun and clamped in place by two heavy bolts.

313. The elevating slide is moved by the elevating gearing system in a circular slideway machined on the rear face of the rear transom, which slideway allows it the movement necessary to change the elevation of the gun from 3.5 degrees depression to 20 degrees elevation. There are provided removable stops in the side of the transom limiting the depression to either 0 degree, —2.5 degrees, or —3.5 degrees, as may be required by the parapet over which the gun is to be fired. Theory requires (in order that the gun when recoiled to the normal position shall always be at the same angle for loading, with the breech at the same height, whatever may be the firing angle) that the elevating slide and its guideway shall be circular and struck with radii, using the center of the trunnion on the elevating band when the gun is in the loading position as a center.

314. The elevation disk consists of a circular wheel carrying the graduated service and subcaliber range scales at its outer and inner circumferences, respectively. It is connected by gearing to a pinion which meshes with gear teeth cut in a collar at the upper end of the elevating worm shaft. The rotation of the worm shaft rotates the pinion and shaft and the circular wheel carrying the scales. A suspended weight takes up backlash in the gear teeth. Degree marks are stamped in the center of the scale for use in checking the disk by a clinometer. The scale is not equicrescent. The degree marks are placed on the disk with the gun mounted upon the carriage, and by the use of a clinometer supported by a rest placed in the muzzle. This is usually done at the time of the shop test.

315. As the ranges corresponding to different angles of elevation above the horizontal depend upon the height at which the gun is mounted above the sea level, the range scales must be graduated after mounting. The range graduations must be calculated for each gun with due regard to the height above sea level and the normal muzzle velocity. These graduations are marked upon the scale in the proper place by the Ordnance Department after emplacement of the carriage. The pointers provide flush zero marks for each scale and are arranged for adjustment in arc, which may be necessary to correct variations in the mechanism or for a particular field of fire if the emplacement settles unevenly. The pointer piece is bolted to a

bracket bolted to the chassis. Adjustment required the use of the clinometer as described above.

316. The elevating handwheel shaft is in two parts joined near the middle by a coupling. It is operated by a handwheel at each end, and drives through a pair of bevel gears which operate the elevating worm. A clutch near the right end of the shaft engages with the right-hand wheel directly so that this wheel can be used for fast elevating only. This clutch is held disengaged by two spiral springs so that the handwheel will not rotate when power is being used. When using the handwheel the operator keeps his foot on a convenient pedal which through levers and a connecting rod keeps the clutch engaged. A clutch is provided near the left end of the handwheel shaft which engages with the left-hand wheel either directly or through a back gear. In the latter case slow motion is obtained.

317. Just inside the slow-motion gearing on the handwheel shaft is a bevel gear meshing with a pinion on a vertical shaft outside of the left chassis. This shaft is divided near the bottom by a clutch and has at the bottom end a bevel gear driven by a pinion on the "speed gear." This "power" clutch and the left-hand wheel clutch are operated by the same maneuvering lever, which has three positions, viz. *hand fast*, *power*, and *hand slow*. The arrangement of levers and links is such that only one clutch is in at a time so that the left-hand wheel is not turned by power and the speed gear is not turned by the handwheel. The "cut-out screw" is that portion of the vertical shaft above the power clutch which is threaded. It is provided with a nut which is prevented from turning by guides and therefore travels along on the screw as it rotates. When it reaches the bottom or top of the screw, the nut throws out the power clutch at the limits of elevation and depression. Stops in the form of collars are provided, to clamp around the screw, for carriages whose depression limit is 0 degree, 2.5 degrees, or —3.5 degrees. The elevating screw actuates the elevating slide to which the lower end of the elevating arm is pivoted. Upon this carriage a hydraulic buffer is provided to absorb the energy of kick down. At the limit of depression of the gun the slide strikes a positive stop. On account of the absence of positive elevation stops, the piece should never be fired at an elevation greater than 30 degrees.

318. The counterbalance device tends to equalize the force required for elevating and for depressing the gun in the loading as well as in the firing position. It consists of a cast-iron weight hung by a double-wire rope which passes over sheaves and is attached to the elevating slide, so as to oppose and partially counterbalance the weight of the slide and one-half the weight of the elevating arm.

319. *Traversing mechanism B.*—The traversing mechanism of this carriage can not be considered essentially different from that of the barbette carriage described under A, paragraph 268. This mecha-

nism comprises a base and racer machined to a conical bearing, a series of conical rollers held in proper position by a distance ring, a traversing rack attached to the base ring, and a train of spur and bevel gears leading from this rack through a Waterbury speed gear to the traversing motor or hand cranks. The principle of the design is essentially the same as that already described in considerable detail. No provision is made in this case, however, for an azimuth observer's cab under the floor. A trapdoor is provided in the floor of the carriage on the left side forward through which the azimuth circle may be observed by a man lying on his stomach giving necessary directions to the operator of the traversing and speed-control handwheel. This scheme of laying the gun in azimuth is not nearly so satisfactory as that provided on the barbette carriage where the observer operates the traversing mechanism.

320. A pinion, at the bottom of a vertical shaft mounted in bearings in the rear clip which is bolted to the racer, meshes in a horizontal traversing rack bolted to the interior cylindrical surface of the base ring. The rotation of the pinion causes the racer and all parts carried thereon to rotate on the rollers and around the pintle. The pinion shaft is driven through a bevel gear at its upper end by a pinion on a horizontal, diagonal shaft extending forward and to the left. A bevel gear at the front end of this diagonal shaft is driven by a pinion on the equalizing shaft, which extends across the carriage and has a bearing in each chassis. Near each end of the shaft just inside the chassis are gears driven by pinions on short shafts extending through the chassis and having hand traversing cranks on their outer ends. These cranks are removable and should be taken off when traversing by power. Power is supplied from a motor through a variable speed gear and three spur gears to the left-hand gear on the equalizing shaft. A clutch serves to disconnect the motor and speed gear when traversing is done by hand.

321. The slow-motion hand traversing mechanism operates through the left-hand traversing crank shaft. A bevel gear on this shaft outside the chassis is fixed to turn with the shaft or set free on it by a pedal-operated clutch. This gear is in mesh with a bevel pinion on an inclined shaft which extends up through the sighting platform and is supported at its upper end in a bearing in the upper gear case, which is bolted to the sight standard. A bevel gear is fitted on the top of the shaft and is driven by a pinion on a short shaft having a handwheel at each end for use by the gun pointer. The clutch mentioned above is operated by a pedal on the sighting platform and is connected to the pedal by a reach rod and lever. The slow-motion handwheels are removable and are kept hung on racks on the sight standard when traversing by power.

322. To prevent excessive shock to the traversing gearing or other parts, due to striking obstructions or too sudden application of power, etc., the bevel gear at the top of the traversing pinion shaft is connected to the shaft by a multiple disk clutch. The hub of the gear is extended in the form of a hollow cylinder, within which the eight friction disks are contained. The four *outer* disks are keyed to the gear and the four *inner* disks are keyed to the shaft which passes up through them. The disk retainer rests on top of the disks, and above it a washer nut screwed onto the top of the shaft compresses them. An oil hole through the nut provides a means of keeping the friction box filled with oil. Another oil hole in the top of the shaft serves to lubricate the thrust bearing, which is a collar screwed onto the shaft below the friction clutch. The collar rests on top of the traversing bracket through which the shaft passes.

323. The adjusting nut should be set up just enough to traverse the carriage by hand without slipping. It is intended that in traversing by power suddenly applied the disks shall slip at first and thus pick up the load gradually.

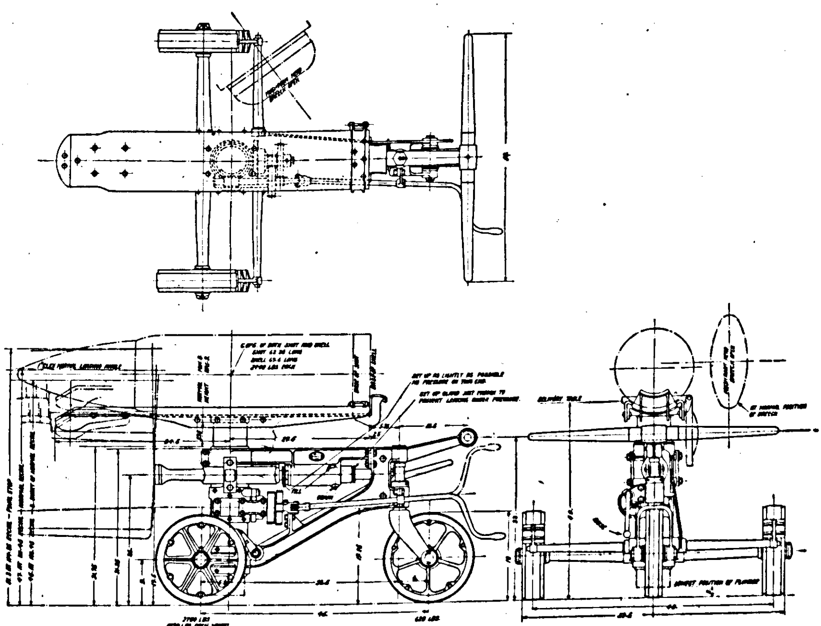
324. The azimuth circle in the form of a sheet-metal cylinder rests on top of and is bolted to the inner base ring flange and carries on its top a bronze scale which is graduated in degrees, the numbers of which are to be added after the carriage is erected in its emplacement. The azimuth pointer, of aluminum alloy, is placed in a recess below the top surface of the racer, which exposes the top of the circle; the pointer is graduated and numbered, as a micrometer, to read one-hundredth of a degree, and is designed to permit final adjustment on the degree marks of the circle at the time the circle is numbered. The recess in the racer is provided with a coaming and cover of steel to protect the pointer and circle from water and accumulations of dirt which would thus find their way to the pintle surfaces.

325. The racer rests and is traversed upon a circle of 30 live, conical, traversing rollers, whose axes are maintained in the radial position by bearings bolted to distance rings. The rollers are of cast steel with flanges on their inner, small ends. They are bored axially for steel pins which are driven in place and project at both ends to form journals. The distance ring is of cast steel made up in six sections, which are bolted together, and have bolted on their upper surfaces the bronze bearings for the traversing rollers. The bearings are formed with a loop on top, by means of which any roller with its bearings can be lifted out of the ring through the holes at the racer joints. The system is kept concentric with the pintle by the flanges on the rollers running in contact with the inner edge of the roller path on the base ring. The inner edge of the

path on the racer is of a larger diameter so as not to come in contact with the flanges.

326. *Loading mechanism*—B.—The loading mechanism of this mount is relatively simple compared with that of the barbette carriage. It comprises simply an ammunition or shot truck of the design shown on Plate 170 on which a single projectile is wheeled to the breech of the gun when it is fully retracted. The projectile must then be shoved off and rammed by 12 men. This is not by any means easy. The powder charge, if provided in four sections, must be brought up on shot trucks or two-man trays and placed on the shot truck. These are rammed likewise by the rammer used for the projectile.

PLATE 170.



SHOT TRUCK FOR 16-INCH DISAPPEARING CARRIAGE.

327. Two crank shafts extending across the carriage have retracting cranks on each end so that 16 men can be employed in retracting by hand. A pinion on each of these shafts meshes in a large gear wheel, which turns on the drum shaft and drives it through an epicyclic gear assembly. The epicyclic gearing provides large gear ratio in compact form without imposing bending loads on the drum shaft (being incased in the bracket of cast steel supported between the retracting beam of cast steel and the rear transom); the arrangement secures rigidity with small shafts. It consists of a cage carrying "opposite" pins upon each of which a gear and pinion revolves, the gears driven by a pinion keyed into the hub of the driving gear

running idle on the drum shaft and the pinions meshing in the fixed rack, causing the cage and clutch to revolve the drum shaft. Two drums are keyed to the shaft and have fastened to them by corrugated-steel clamps two 1.25-inch wire ropes, which wind in the grooves on the drum. The drums are made conical to give an approximately equal torque throughout retraction. From the drums the ropes pass around guide pulleys at the rear of the carriage and are hooked to the upper ends of the gun levers. When not in use the ropes are wound upon the drums so that the loops just hang free of the idler sheaves. A clutch is provided so that the drum shaft can be disconnected from the gearing and the retracting ropes pulled out rapidly. The handle of the clutch shipper is located on the left side of the carriage. The clutch is engaged when the handle is pushed in. A band brake operated by a lever on the left side of the carriage serves to prevent overrunning of the drums and consequent injury to the ropes by bending backward over a small radius. A ratchet on one of the crank shafts and a pawl prevent the load from overhauling the gearing, and serve to hold the gun in any position of retraction before the rack pawls begin to engage in the rack. The retracting pawl may be thrown out to permit slacking away on the ropes by turning the cranks backward. After taking up the slack in the ropes and putting some strain on them they should be vibrated slightly, and if found to be unequally loaded adjustment should be made at the rope clamps on the drums. After the loop of the rope is placed over the hook on the gun levers, and while winding up the slack, especial care should be taken that the rope is guided to the pulleys without any kinks or any slack, and that the coils lie smoothly upon the drums without crossing the ridges between the grooves. The wire ropes should always be detached from the gun-lever hooks before tripping. When retracting by power, the hand cranks should be removed. Power is supplied by a motor whose pinion meshes in a gear near the right end of the forward crank shaft. This gear is connected to the crank shaft by a clutch operated by a handle outside the left chassis. The clutch is engaged when the handle is shoved in.

328. *Chassis*—B.—The chassis, of cast steel, comprises two main side members bolted, doweled, and keyed to the races and united at the front and rear ends of transoms. The upper surfaces of the chassis form the recoil-roller paths and slope 1 degree to the front to facilitate the return of the piece to the firing position, thus reducing the necessary preponderance of the counterweight. The chassis also provide the necessary bearings or supports for all the mechanism and, with the racer, support all the minor attachments. The front transom, of cast steel, rigidly unites the front ends of the chassis and with them supports the "drop" of the counterweight on the pawls of the tripping gear. The real transom, of cast steel, rigidly unites

the rear ends of the chassis, and also extends below the racer so as to provide, central on its rear side, the guideway for the elevating slide. Bearings for the elevating worm shaft and pad surfaces for brackets are also provided.

329. *Base ring*—B.—The base ring, 24 feet in diameter, is made of cast steel, in halves, bolted and keyed together, and is held in position on the foundation by fourteen 3-inch bolts around its outer edge and sixteen 3-inch bolts around its inner edge. Fourteen screws for leveling the base ring are set against steel thrust plates. There is also a circle of 14 holes threaded to take 2.5-inch standpipes for use in pouring grout. The base ring, in addition to having the lower roller path on its upper surface, has an annular flange near its inner edge, forming the pintle for the carriage. This flange has near its top a lip inward, under which the clips engage, and on its top edge the azimuth circle. To its inner face is bolted the traversing rack. The outer annular flange on the ring projects upward outside of the traversing rollers. Its top surface is machined to form a contact surface for the felt dust guard. The cavities on each side of the roller path are drained into the pit through passages in the inner edge of the ring. Tapped holes can be found inside of the pintle flange for attaching the traversing stops in any required position.

330. Following is a tabulation of miscellaneous data on this carriage:

FORCES AND STRESSES.

The force of the powder gases is 8,700,000 pounds.

This force is reduced at the trunnion to $P=866,000$ pounds; $P_1=860,000$ at 0 degree elevation.

At maximum elevation P_1, however, becomes 5,000,000 and the carriage parts must be designed to withstand this force. It is interesting to note that P_7 exceeds 2,000,000 pounds.

The value of the counterweight in absorbing the energy of firing is therefore apparent.

The energy of recoil is dissipated—

(*a*) In raising the counterweight.

(*b*) In throttling oil in the varying orifices in the recoil cylinders which are built into the top carriage.

(*c*) In moving the gun, gun lever, and top carriage from in battery to the recoil position.

The piston-rod pull is 616,000 pounds and is assumed to be constant throughout the length of recoil.

It will be seen that the force acting on the upper end of elevating arm P_2 and P_3 is very large, this force having been computed on the assumption that this arm is rigid.

In order to reduce the force on the elevating arm, it has been made elastic—that is, a second recoil mechanism has been introduced. This recoil mechanism allows the arm to shorten when a large stress is brought upon it. As soon as the stress is relieved the arm returns to its original length.

The maximum stress occurs in different members at different angles of elevation. It is therefore necessary to make calculations at various angles of elevation to determine the maximum stress which occurs in each member.

The introduction of the elastic arm slightly increases the stress in the gun levers and other members which must be computed on this basis, the arm still fulfilling its function of keeping the gun at proper elevation.

The force which the elevating arm must carry is reduced from about 4,000,000 pounds to less than 1,000,000 pounds by making it elastic.

Pull on each piston rod, 220,000 pounds.

Weights.

Total weight of carriage ---------------------------------pounds--	1,328,025
Total weight suspended from gun lever necessary to bring gun into battery ---------------------------------pounds--	610,219
Weight of gun, loaded ---------------------------------pounds--	343,851
Total weight of gun and carriage ---------------------------------pounds--	1,671,876
Total rotating weight ---------------------------------pounds--	1,563,024

TESTS.

Each piston rod: 450,000 pounds pull between end nut and piston.

Recoil cylinders: 3,880 pounds per square inch hydraulic pressure with piping and valves assembled.

Hurter cylinder: 5,000 pounds per square inch in hydraulic pressure with piping and coupling removed.

Kick-down cylinders: 10,000 pounds per square inch hydraulic pressure with piston and packing assembled.

Kick-down piston rod: 867,000 pounds pull between end nut and piston.

OPERATION, MOTIONS, ETC.

Maximum elevation, 30 degrees.

Loading angle, 1 degree, normal recoil.

Movement of top carriage, 89.0078 inches.

Rotation of axle, 80 degrees.

Movement of counterweight, 111.4521 inches at normal recoil; 3.3969 inches farther to final stop.

Normal recoil, recoil cylinder, 89.0078 inches.

Void in each recoil cylinder to provide for expansion and unopposed withdrawal of buffers when firing, 980 cubic inches.

Normal movement of recoil hurter, 3.10975 inches.

Maximum movement, 5.50665 inches.

Void of kick-down cylinders when filled at normal recoil to 20 degrees elevation, 87 cubic inches; 15 degrees elevation provides less void and 25 per cent elevation more void.

Outer kick-down springs are loaded; assembled height not less than 11,670 pounds.

Intermediate kick-down springs are loaded; assembled height not less than 4,725 pounds.

Inner kick-down springs are loaded; assembled height not less than 2,365 pounds.

Elevating gear ratio: Makes 221.85 revolutions from —5 degrees to +30 degrees elevation.

Rate of firing, one shot per minute, at a range of 40,000 yards.

EQUIPMENT, DESIGN, ETC.

(*a*) Retracting cranks 4; 16 men required.
(*b*) Pinching-in levers 2; 2 men required.
(*c*) Traversing cranks 2; 3 men required.
(*d*) Handwheels at sight, slow motion, 2; 1 man required.
(*e*) Tripping levers, 2; 3 or 4 men required.
(*f*) Elevating handwheels 2; 2 men required.
(*g*) Left elevating wheel, slow motion, 1; 1 man required.

Number of traversing rollers 30; type conical.

The retracting equipment is arranged to permit of power retracting from the firing position to approximately 3 inches less than "normal recoil" as indicated by the recoil scale in 4 minutes. Motor 15 horsepower. Controller to stop the motor at any point in 5 seconds, permitting the gun to be stopped at any prearranged point with certainty and precision.

Traversing equipment: The electrical equipment provided for traversing the gun carriage is arranged to permit the traversing gear being operated by constant-speed shunt-wound motor, 7½ horsepower, driving through a hydraulic variable-speed gear, the hydraulic gear being so designed that while the armature of the motor turns continuously in one direction at 500 revolutions per minute operating the driven or "A" end, the speed of the driving end of the apparatus or "B" end may be varied at will from 500 revolutions per minute to zero. The rate of revolution of the "B" end of shaft is controlled by a suitable controlling mechanism with one

operating handwheel located on the left chassis near the azimuth pointer and another located at the sight, operating the control shaft on the pump or "A" end of machine. The gear turns the carriage at a maximum rate of 110 degrees per minute and at the minimum rate of about 0.25 degrees per minute. The carriage can be accelerated from rest and brought to its full speed to 110 degrees per minute in 4.6 seconds of time.

Elevating equipment: The electrical equipment provided for elevating the gun is arranged to permit the elevating gear being operated by a constant-speed shunt-wound motor of 4 horsepower driving through a hydraulic gear being so designed that while the armature of the motor turns continuously in one direction at 500 revolutions per minute operating the driven or "A" end, the speed of the driving end of the apparatus or "B" end may be varied at will from 500 revolutions per minute to zero. The rate of revolution of the "B" end of shaft is controlled by a suitable controlling mechanism with operating handwheel located on the left chassis near the range disk, operating the control shaft on the pump or "A" end of the machine. The gear will elevate the gun in battery, loaded, from —5 degrees to —30 degrees in 1.7 minutes as a maximum and at a minimum of about one twenty-fifth of 1 degree per minute. The gun can be brought to its full speed of elevation in 1 second of time.

3. 16-INCH 25-CALIBER HOWITZER ON BARBETTE CARRIAGE, MODEL 1920.

331. *Cannon—C.*—This cannon, Plate 171, may be termed a product of the World War in that observation of the effect of large-caliber howitzers in the field in France led to the idea of the construction of a 25-caliber howitzer for use in our seacoast fortifications. The cannon is of the built-up type and uses the same projectile as the 16-inch 50-caliber gun described under A, paragraph 252. Further data with reference to the details of construction are given in the table of information. A cast-steel counterweight is assembled mechanically to the breech end of the cannon and serves as the means of connecting the recoil and recuperator pistons with the cannon. The howitzer is fitted with a steel spline or key sliding in a splineway in the cradle, thereby serving to prevent rotation of the gun on firing. It may be well to mention here a point that was not given much attention under A with reference to the means of anchoring the cannon in a carriage to prevent rotation. As the gun is fired and the projectile is forced up the bore, a part of the energy of the powder gasses is used in rotating the projectile. This rotation is brought about through the gripping of the lands of the bore on the copper rotating band of the projectile, and as the travel of the

grees to release or lock it. The block, except when in place in the breech of the gun, is supported on a tray which is hinged about a vertical pin passing through the two lugs of the hinges. The rear of the block is machined out, as in block on Plate 264, and a spindle with mushroom head quite similar in construction to that already described is provided to protect the forward face of the block and to clamp the split rings and obturator pad against the breechblock. This needs no further description. The breechblock is rotated by means of a hand crank through a worm, worm wheel, the vertical hinge pin, and a combination or compound gear on the upper end of the pin. A projection on the rear of the breechblock is machined to a worm with which this compound gear engages as the crank is rotated (assuming the block to be closed), thereby rotating the vertical pin. The breechblock is rotated by the compound gear, which at first serves as a worm. When the block has thus been rotated through 45 degrees the worm jams in the worm wheel, which is discontinued, and the compound gear now becomes a spur engaging with a series of grooves or cogs machined in one of the unthreaded segments of the breechblock, serving to slide it to the rear on the tray. When the block has reached the limit of its backward movement the gear again jams, a latch is released, and further turning of the crank simply serves to rotate the tray around the hinge pin until the block is sufficiently out of the way for loading.

344. The breech is closed simply by reversing the motion of the crank, thereby first swinging the tray back into closing position and engaging the latch, then moving the breechblock forward until it is in position to be rotated, when the combination gear ceases to serve as a spur and begins to serve as a worm, rotating the block until it is completely locked.

345. *Firing mechanism.*—See A, paragraph 257.

346. *Recoil mechanism.*—See B, paragraph 292. The only respect in which this recoil mechanism can be said to differ from that described under B is that since this is a 35-caliber gun of a weight considerably less than the 50-caliber gun on the model 1917 carriage, the counterweight is lighter and the recoil cylinders are built to absorb less energy of recoil.

347. *Recuperator mechanism.*—See B, paragraph 307.

348. *Elevating mechanism.*—See B, paragraph 310. It is possible to elevate this gun only to 20 degrees, as against the 30 degrees provided on the 50-caliber gun; and an 8-inch kick-down cylinder is provided here, as compared with a 16-inch cylinder for the other gun. The piece can be elevated from −5 degrees to +20 degrees, stops being arranged to limit the depression to either horizontal or −2.5 degrees when the height of the parapet requires it. The elevating

mechanism is so constructed that the loading angle is approximately 1 degree, no matter what the setting in elevation.

349. *Traversing mechanism.*—See B, paragraph 319. The traversing mechanism of the 50-caliber gun described under B provides for all-around fire; that is, 360 degrees traverse. It is possible to traverse this carriage through 360 degrees in maneuvers, but it was not intended that it should be operated through more than 170 degrees. The stops can be so arranged as to limit traversing to 60 degrees, 70 degrees, 90 degrees, or 110 degrees on either side of the front of the battery. When in the execution of maneuvers it becomes necessary to traverse the breech to the front, which can be done with the gun in battery, the fixed stops and the cams of the traversing controller stops must be removed and care exercised that the electric cable in the pit is not injured by traversing the counterweight against it.

350. *Loading mechanism.*—See B, paragraph 326.

351. *Chassis.*—See B, paragraph 328.

352. *Base.*—See B, paragraph 329.

5 AND 5A. 14-INCH 34-CALIBER GUN, MODELS OF 1907, 1907MI, AND 1910, ON DISAPPEARING CARRIAGE, MODELS OF 1907 AND 1907 MI.

353. This gun and carriage are illustrated on Plates 175 and 176.

354. *Cannon E.*—The 34-caliber gun, model of 1907, used on some of these carriages is of the wire-wound type, Plate 175, and as contrasted with the 16-inch 50-caliber gun, A, paragraph 252, comprises only one tube, about which the wire is wound and over which is shrunk a jacket, four hoops, and a trunnion hoop. The gun is rifled with 126 grooves twisting to the right at a varying pitch of from one turn in 50 calibers at the origin to one in 25 calibers at the muzzle. The grooves are 0.2091 inch wide by 0.07 deep. The lands are 0.14 inch wide. The powder chamber is cylindrical, has a maximum diameter of 16.8 inches, a length of 68.195 inches, and a capacity of 15,000 cubic inches. The muzzle velocity at which the gun is operated is 2,150 feet per second, with a weight of charge of 349 pounds and a maximum pressure of 38,000 pounds per square inch and a projectile weighing 1,560 pounds.

355. The 14-inch gun, model of 1907 MI, Plate 175, is of the built-up type, and comprises one tube, nine hoops, and a trunnion hoop. Its weight is 53 tons, as against the 49.95 tons for the wire-wound gun, model of 1907, even though it is 5 inches shorter—that is, 490 inches, as against 495 for the other gun. The powder chamber and rifling are identical in every respect. The powder charge, pressure, weight of projectile, and muzzle velocity are likewise the same.

356. The 14-inch gun of model 1910 is 40 calibers long, as contrasted with the 34 calibers of the 1907 guns, is wire wound, but com-

prises two tubes instead of one for the 1907 gun. This gun comprises two tubes, a wire envelope, jacket, trunnion hoop, and three muzzle hoops, together with numerous locking hoops. Its weight is 61.9 tons, length 40 calibers, or 579 inches. The powder chamber is cylindrical, has a maximum diameter of 16.8 inches, length of 88.415 inches, and a capacity of 19,323 inches. The rifling is identical with that of the previous two guns. The powder charge is 430 pounds, the maximum powder pressure 38,000 pounds per square inch, projectile weight 1,560 pounds, and muzzle velocity 2,350 feet per second.

357. *Breech mechanism.*—See B, paragraph 279.

358. *Firing mechanism.*—See B, paragraph 287.

359. *Recoil mechanism D.*—This recoil mechanism, Plate 176, differs from the last described in that it comprises a single recoil cylinder mounted in the counterweight, as contrasted with the mechanisms containing two recoil cylinders in a top carriage. It will be observed that the cylinder is contained in the counterweight and the piston has its main connection with a beam across the bottom of the well of the emplacement and is pinned at its upper end to the chassis. The length of recoil of the gun arm axle is 73.4281 inches, and the stroke of the piston in the recoil cylinder is 96.33 inches. In the lower cylinder head there is a recess 12 inches in diameter. On the piston below the head is a corresponding enlargement, which enters this recess with slight clearance. If at the end of recoil the energy has not been normally absorbed, these parts, acting as a dashpot, provide a safeguard against possible injury to the carriage and take the place of the buffers on the rear of the chassis of carriages having horizontal cylinders.

360. The filling and drain plugs are in the upper and lower cylinder heads, respectively. The two filling plugs are in the form of tap bolts; one additional is supplied. Copper tubes extend down inside the cylinder from the filling holes to prevent filling above a certain point. This leaves an air space in the upper end of the cylinder. The drain plug is so arranged that the oil can be withdrawn from the cylinder without unscrewing the plug more than a few turns. A brass gutter is bolted to the piston-rod beam under the plug for the purpose of conducting the oil within reach of a receptacle.

361. The piston and rod are of forged steel in two pieces, the lower part of the rod being formed in one piece with the piston The lower end passes through a hole in the piston-rod beam. Two nuts engage on threaded portions of the rod above and below the beam, cylindrical portions on them seating in counterbores in the beam, thus aligning the rod. The upper end of the rod is bored axially to

receive the stem and body of the recoil valve. At the piston two grooves surround the bore. Six holes radiate from each of these grooves, one set opening on each side of the piston. Oil can therefore pass from one side of the piston to the other in two ways—first by the outside of the piston head, through the diametral clearance of 0.02 inch and the throttling grooves; and, second, through the two sets of radial holes. Passage through the radial holes is restricted by the recoil-valve body. This is a bronze bar fitting closely in the piston-rod bore, opposite the piston. It has a diametral slot 0.625 inch wide, 2 inches long, and 2.843 inches from the lower end. With the recoil valve open this slot reaches from one groove to the other. As the valve body is withdrawn upward the portion of the slot open to the lower groove decreases to zero, thus closing the passage between the two sets of radial holes.

362. At the upper end of the piston rod a bronze valve-stem nut is fitted into the bore and secured by a bronze feather, driven and pinned in the nut and free on piston rod. The valve stem is a steel rod connecting the valve body with the valve-stem nut for the purpose of actuating the former. The upper end of the valve stem has a flatted portion over which the locking disk is seated. In order to remove the valve the valve-stem nut must be taken out. The locking disk is of bronze, 7.5 inches in diameter, and has 11 notches on its circumference to indicate opened, closed, and 9 intermediate positions of the recoil valve. One notch is marked "Closed"; the others are numbered from 1 to 10, inclusive. When the shoulder on the valve stem stops against the lower end of the valve-stem nut, the notch marked "Closed" is toward the front of the carriage and opposite the hasp, and the bottom of the slot in the valve-stem body is 0.25 inch above the lower groove in the piston-rod bore. When the disk is turned clockwise 90 degrees, the valve stem descends 0.25 inch and brings the bottom of the slot to coincide with the upper edge of the lower groove. A further movement of 18 degrees uncovers the lower groove 0.05 inch, or an area of 0.02 square inch, and brings the first notch of the locking disk opposite the hasp. Similarly, each additional notch opens the passage through the piston 0.05 inch. When the tenth notch is opposite the hasp the lower groove is uncovered 0.05 inch, and the valve is fully open.

363. The upper end of the piston rod is flatted to retain it in a fixed position with respect to rotation. A piston-rod bracket of cast steel maintains the upper end of the piston rod in alignment. The hasp bracket is bolted to the piston-rod bracket in front of the piston-rod seating against the flatted portion of the latter. The hasp, by engaging in notches on the locking disk, retains the recoil valve at any desired setting. A flange on the top of it prevents the locking disk from

moving vertically when the hasp is engaged. A slot in the hasp passes over a lug on the hasp bracket, after which a padlock is secured to the lug, preventing any unauthorized change in the setting of the recoil valve. The normal movement of the counterweight during recoil is 102.331 inches, with provision for an additional 3.226 inches. During part of this additional recoil the recoil buffer previously described would act to bring the carriage to rest without excessive shock. An indicator scale to measure the recoil is secured to the cam on either side of the counterweight frames so as to be visible through the oval openings in the chassis to the rear of the standards. Numbered graduations are cast on them at intervals of 1 inch, reading from 77 to 105 inches. Pointers are attached to inside of chassis.

364. The recoil valve is the only means provided for varying the length of recoil, and no attempt should be made to use other means for this purpose. Although the setting of the recoil valve slightly affects counter recoil, it should not be used to regulate the latter movement. For firing with all charges the recoil cylinder should be kept filled to the level of the filling-hole tubes with the oil issued for this purpose.

365. *Recuperator mechanism C.*—A counter-recoil buffer is fitted to the forward end of each chassis roller path. The buffer cylinder is securely bolted to the chassis and has on its rear face a stop with machined surface, against which a corresponding machined surface on the forward end of the top carriage abuts when the gun is fully in battery. Each end of either recoil-buffer cylinder is closed by a stuffiing box fitted with hydraulic packing. Each cylinder is provided with a filling plug located on the top end in front of the piston head when in its rear position. A bronze plate with instructions as to filling the cylinder is secured by screws near the filling plug. Two holes extend through the wall of the cylinder, from the lowest element of the bore, vertically downward. To these openings are coupled the pipes connecting with the buffer valve. The openings are located longitudinally, one just in front of the rear cylinder head, so that it is always in rear of the piston; the other, 3 inches in rear of the front cylinder head.

366. The piston rod extends through both stuffing boxes. The piston, located approximately in the middle of the rod, is made of bronze, 13.98 inches in diameter, allowing 0.02-inch clearance between it and the smallest diameter (14 inches) of the cylinder. On carriages Nos. 1 and 2 the cylinder is bored parallel 14.16 inches in diameter from the inner end of the rear cylinder head for 12.275 inches, then tapering for 3 inches to 14.116 inches in diameter, then parallel for 2.125 inches the balance of the length of the bore to the front cylinder head. On carriages Nos. 3, 4, and 5 there is one continuous taper. The carriages, model of 1907 MI, have similar buffers, but diameters of cyl-

inders are smaller. A cast-steel yoke, with a hole in each end for the spring rods, is attached to the front end of the piston rod. On each side of the buffer cylinder is a spring cylinder, with a cast-steel head screwed in the front end and containing three flat helical springs, with separators between and a rod arranged to compress the springs when pulled to the front by the yoke. A piston movement of 14 inches is provided for.

367. The action of each counter-recoil buffer is as follows: When the gun is retracted from battery, the buffer springs, acting against their fixed supports in front, force the spring compressors, spring rods, yoke, and piston rod to the rear until stopped by the nuts on the front end of the spring-compressor rods coming to rest against the recessed shoulder in the front of the front spring cylinder head. In this position the rear end of the piston rod projects 12 inches in rear of the top carriage stop on the end of the cylinder. The interior diameter of the cylinder is largest at the rear end, and when the piston is in position to commence the forward stroke the annular space is 0.09 inch wide between the piston and the wall of the cylinder. When the gun rises into battery the top carriage strikes the projecting ends of each piston rod and forces them to the front, compressing the springs, and forcing the oil from front to rear past the piston, and when the buffer valve is open, also through the buffer valve and pipes. As the gun returns from battery the flow of oil, under action of the buffer springs, is, of course, in the opposite direction along the same paths. The cylinder bore is tapered in order to provide, as nearly as possible, a uniform resistance in bringing the top carriage to rest against the stop. By means of the buffer valve this resistance may be varied within sufficient limits to always insure proper action of the buffer and to prevent shock.

368. If, for any reason, the pawls fail to retain the gun out of battery after recoil, it is necessary, to prevent serious injury to the carriage, that the buffer pistons be at their rearward position before the top carriage strikes them. Otherwise, the buffers will not do their full work of retardation, and the top carriage will strike the stops with more or less shock. The buffer springs have been designed to return the buffer pistons in time, assuming that the stuffing boxes do not offer an unreasonable frictional resistance. It is therefore important to screw up the glands only sufficiently to prevent leakage. It is necessary to tighten the front stuffing box more than the rear one.

369. Both recoil buffers are joined to the buffer valve, the different settings of which, under varying conditions affecting the velocity of counter recoil, enable the energy of counter recoil to be absorbed without shock to the carriage. Aside from mechanical variations and those due to differences in the elements of loading,

atmospheric temperature and the loading position affect the counter recoil. The equalizing and throttling pipes serve to connect the buffer valve to the buffer cylinders, to equalize the pressure in the buffer cylinders, and to facilitate filling them. Four plugs are furnished to close the buffer cylinders in case these pipes are damaged in action. The buffer valve is located above the center of the oval opening in the front transom, to which it is attached by two bolts. It is accessible from the front of the carriage, and consists essentially of a valve body, gland, disk, a handle of bronze, and a stem of steel and bronze. Part of the oil displaced in the counter-recoil buffers during counter recoil passes through this valve. If the valve stem be turned clockwise, its conical point will bear on the valve seat and close the valve; if the stem be turned counterclockwise, the opening about its point will increase.

370. The disk is fixed to the valve body concentric with the stem. On the front face is an annular flange with 80 internal teeth, in which 3 corresponding teeth on the handle engage in order to retain the valve at any desired setting. The teeth on the disk are numbered counterclockwise from 0 to 80 at intervals of 5 teeth. A pin set in the face of the disk prevents the handle being turned more than 360 degrees. A stuffing box is formed in the body around the stem, in which four rings of packing are placed. An emptying plug is located at the bottom of the valve body and affords a means of draining the buffer cylinders. Settings of the buffer valve are best determined by trial. The setting of the recoil valve should be considered in setting the buffer valve. With a higher setting of the recoil valve, counter recoil will be more free, and consequently the buffer-valve setting should be lower. The counter recoil should be regulated by settings of the counter-recoil buffer valve and not by adding or removing counterweight.

371. *Elevating mechanism*—C.—The limit of elevation of these guns is 15 degrees and no kick-down cylinder has been incorporated in the elevating arm. To prevent breakage or erratic "jump" from the severe downward shock received through the elevating arm when the gun is fired, arrangement is made to transmit the resulting stress between the elevating slide and slide nut by double sets of helical springs, one set on each side of the elevating screw. In order that the elevating slide shall return to its proper position after firing, the springs are given an initial compression sufficient to positively return the slide to a bearing against the heads of the spring-compressing bolts. This initial compression is very carefully adjusted during the shop test of the carriage. The elevating arm is hinged to the bottom of the band, as against the side trunnions for previously described carriages.

372. A small counterweight attached by a wire rope to the elevation disk tends to overcome all backlash which may exist in the gearing and hold the disk to its true position at any desired elevation. The elevating slide is a steel casting with bronze liners on its side and lower edges. It slides in ways provided in the rear transom and is held in place by cast-steel gibs. A counterbalance device is provided to equalize, as nearly as possible, the force required for elevating and depressing the gun while in either the loading or the firing position.

373. *Traversing mechanism, loading mechanism, chassis and base.*—See B, paragraphs 319, 326, 328, and 329, respectively.

6. 14-INCH, 40 CALIBER GUNS, MODELS OF 1909, ON TURRET MOUNTINGS, MODEL OF 1909.

374. This unique installation is worthy of serious consideration and is mentioned by some authorities as a preferable type for many of our coast-defense sites. As one studies this design he is reminded of a great number of the mounts installed by the Germans along the coast of Belgium. The Germans knew full well when they installed these guns and carriages about Ostend and from Ostend to the Dutch border that they would be compelled to cope not only with the British Navy, but with the British and French air forces as well. Shortly after the famous raid of the spring of 1917 on Ostend and Zeebrugge, they installed on the promenade at Zeebrugge four turrets that either had been intended for a battleship or had been removed from some ship that probably had been condemned for further use. Several of the 15-inch guns of the battery Deutchland, just north of Ostend, were so heavily armored that they might, in a manner, be considered turrets also. Other guns of smaller caliber at the Harbor of Ostend, and below the city in front of the Royal Palace Hotel, were similarly armored. A study of the illustrations given in Appendix III, of railway artillery, Volume I, will show how valuable some protection was against attacks from the air. Bomb craters are to be found in all directions about practically every mount of any size in the stretch of 28 miles of fortified coast. This record, together with demonstrations that we have had during the past few years of the effectiveness of the airplanes at sea against ships, may well cause us to consider seriously this design for future installations. The cost of gun mounts and emplacements of this type, however, is so great in comparison with the simpler types that, at this time, considerations of economy necessitates the use of the latter, even though they lack the protection of armor against attacks from the air.

375. *Emplacement.*—The emplacement is of concrete and has steel barbette armor embedded in it around the upper edge of the well

for each turret, Plate 177. The high turret has a field of fire of 360 degrees and may be revolved continuously in either direction. The low turret has a field of fire of 230 degrees, divided into two sections of 115 degrees each by the axis of the fortification. Each turret is divided vertically into five principal compartments:

(*a*) The gun compartment, extending from the top of the turret to the bottom of the pan, Plate 178.

(*b*) The upper handling room, a compartment extending 13 feet downward from the pan bottom.

(*c*) The electrical compartment, 72 inches high in the low turret and 156 inches high in the high turret, extending downward from the floor of the upper handling room, Plate 177.

(*d*) The lower handling room, the floor of which is on the magazine level, Plate 177.

(*e*) The pit, 108 inches in diameter, under the base plate in the lower handling room, Plate 177.

376. The gun compartment is divided longitudinally into two chambers, one for each gun. Each gun chamber is a complete unit and the openings between them should be kept closed while the guns are being served. The gun chambers contain the guns and recoil mechanism, elevating mechanism, the rammers, the hand traversing mechanism, the control mechanism for the traversing gear, and the sights. The periscope is placed in the booth at the rear of the gun chambers for the use of the officer in command of the turret, Plate 178. One complete charge for each gun is brought into the gun chamber on each trip of the upper ammunition car, which runs on rails extending downward into the upper handling room. The gun chambers are kept under a pressure of about 11 pounds per square foot, the air being supplied from blowers in the electrical compartment. The upper handling room is divided into two chambers, each complete in itself, corresponding to the divisions of the gun compartment. The principal function of the upper handling room is to provide an air lock between the gun compartment and the lower handling room. It is shut off at all times from the gun compartment by the upper ammunition car trunk which is provided with automatic doors operating in conjunction with the doors of the cars. Communication is closed to the lower handling room and magazine by the lower ammunition car which completely seals its trunk. The ammunition on arriving in the upper handling room is removed from the lower car and transferred to the upper car. In the service of the guns not more than one powder charge for each gun should be in the upper handling room at any one instant. In addition to the apparatus for transferring the ammunition from the lower car to the upper car, the upper handling room contains the motors and gearing for the upper and lower ammunition hoists, the motors and hydraulic

pump for the traversing gear, and the auxiliary traversing control mechanism. The two compartments of the upper handling room should be kept closed from each other, from the gun compartments, and from the electrical compartment when the guns are being served.

377. The electrical compartment contains the switchboard on which are arranged the electrical controlling and starting apparatus for the ammunition hoists, the traversing mechanism, the elevating gear, the rammer, the firing circuits, the ventilating fan motors, the circuits for the data transmitters, and the lighting circuits. It also contains the two ventilating fans for maintaining pressure in the gun compartment, the compressed air relay tanks for the gas ejector system, and the motor generator sets for the firing circuits and the data transmitter circuits. The rammer motor and controller, and the master controllers for the upper ammunition hoists, are necessarily placed in the gun compartments, and the master controllers for the lower ammunition hoists are placed in the upper handling room. These circuits, except for the rammer, carry a very small amount of current, not exceeding 2 amperes each, and the making and breaking of all circuits carrying a large amount of current takes place only in the electrical compartment, which compartment should be completely isolated from all others during the service of the guns. Special precautions have been taken to provide adequate protection for the rammer wiring in the gun compartment. The lower handling room contains the loading table and other apparatus for expeditiously loading the projectiles into the lower ammunition car. The projectiles are brought into this room from the magazines on trolley hoists, and the powder is brought in and placed in the ammuntion cars by hand. The pit under the lower handling room contains the rotating drum for collecting the current for the power, lighting, telephone, and data transmitter circuits. Its also contains the switches for connecting the drum with the outside mains and a swivel joint for the compressed air pipe and voice tube.

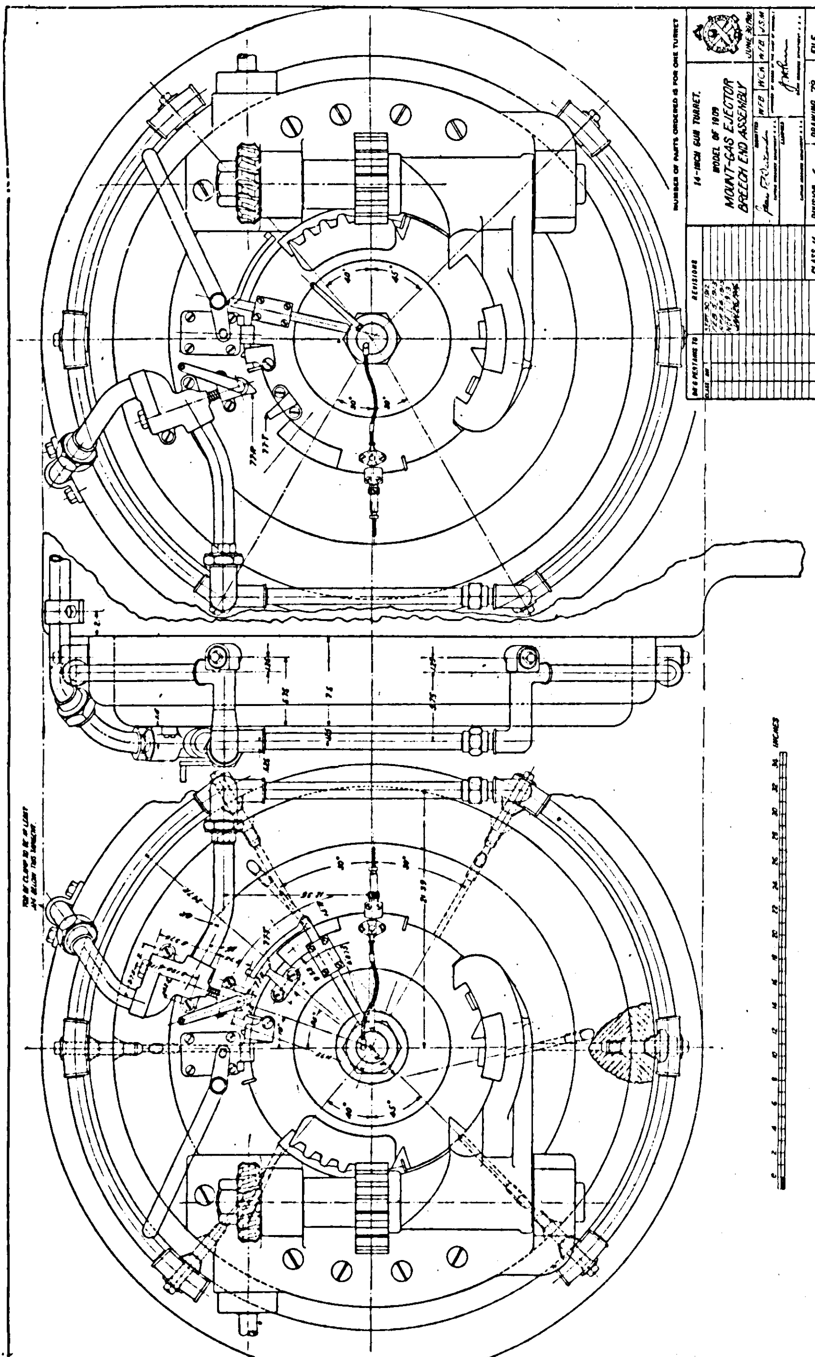
378. *Cannon.*—The guns are of 14-inch caliber, 40 calibers long, model of 1909, and fire a 1,660-pound capped projectile at a muzzle velocity of 2,350 feet per second, with a powder charge of about 440 pounds. They are rifled with 126 grooves which progress in their twist to the right from one turn in 50 calibers at the origin of rifling to one turn in 25 calibers at the muzzle. These grooves are 0.2091 inch wide by 0.07 inch deep and the lands are 0.14 inch wide. The velocity of rotation of the projectile at the muzzle is 4,856 turns per minute. The gun is carried in a cast-steel cradle which is swung by its trunnions in the trunnion bearings of a cast-steel yoke, which both connects and rests upon the structural steel side girders or frames of the carriage. The cradle comprises a cast-steel sleeve in which the gun slides in recoil and counterrecoil on annular Tobin

bronze liners, which are attached to the inside circumference of the cradle. The gun is prevented from rotating by a key which is fitted to its top element and which slides in a slot cut in the cradle.

379. *Breech mechanism.*—The breech mechanism, Plate 179, comprises a Welin stepped-thread breechblock divided into 12 sections in three diameters with the usual mushroom head with split ring and asbestos obturating pad. This breech is carried on the usual tray which is swung about the hinge pin passing through the hinge lugs fastened to the breech of the gun. A rack is milled along the breechblock to within a short distance of the front end, and a short sector (approximately 30 degrees) of worm wheel is attached to the breech face of the block, the one end of the sector coinciding approximately with the end of the rack. A compound gear, part spur and part worm, is keyed to the hinge pin, to which a complete worm wheel is likewise attached at the top, meshing with the worm on the end of the shaft of the operating crank. The operation is, then, in opening the breech, that the operator proceeds to turn the crank in one direction, thereby rotating the hinge pin through the worm and worm wheel and rotating the breechblock through the action of the worm section of the compound gear on the worm wheel sector attached to the rear end of the breechblock. When the breechblock has been rotated through approximately 30 degrees, the spur gear section of the compound gear meshes with the rack on the side of the breechblock and draws it to the rear on a tray, the tray being held to the breech face of the gun by a latch until the breechblock reaches its rear position. When the breechblock reaches its rear position, the spur pinion chocks in the rack and the tray latch is released at the same time. Continued turning of the crank then results in a rotation of the tray and the breechblock along with the hinge pin until the breechblock is completely swung out of the way. A reversal of this procedure closes the block.

380. A gas ejector is likewise provided for sweeping the gases out of the gun immediately on opening of the breech and before the powder for the next round is brought up. Compressed air at 175 pounds pressure is brought into the turret from an air compressor and is led through pipes to a valve on the breech of the gun, Plate 179. When opening the breech, the rotation of the block causes the tripping block to strike the valve and open it. This allows the air to pass into the bore of the gun through six openings around the circumference. Valves are provided to cut off the supply of air from the gun when desired. These gas ejectors are quite necessary in this type of installation, as the rush of air from the muzzle back, due to a strong wind, would make the turret quite unendurable, and at the same time might sweep back some burning fragments of powder

PLATE 179.

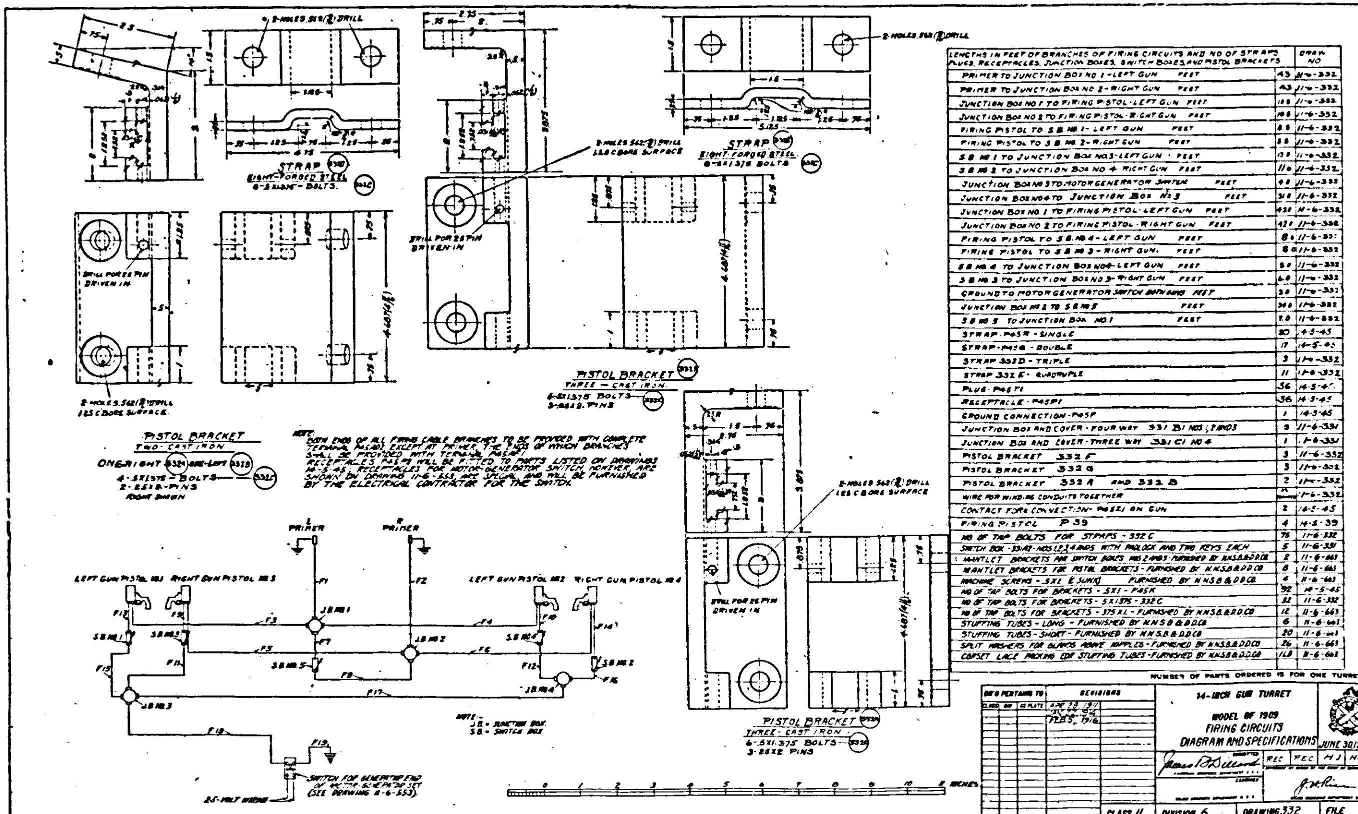

NUMBER OF PARTS ORDERED IS FOR ONE TURRET
14-INCH GUN TURRET.
MODEL OF 1909
MOUNT-GAS EJECTOR
BREECH END ASSEMBLY
JUNE 30 1910
REVISIONS
CLASS 11
DIVISION 6
DRAWING 79
FILE
INCHES

bag, with the possibility of an explosion. The moderate air pressure maintained in the gun compartment by the blowers tends to minimize this possibility after the block has been opened.

381. *Firing mechanism.*—Guns in these turrets are fired by means of electricity. Electric primers have been described already, and consist of the usual type of primer provided with wires connected at their forward end by a heating element which ignites the charge on the passage through it of a suitable current. A safety mechanism is provided against the accidental firing of these guns before the breech is closed. This comprises simply a break in the electric circuit, Plate 179, which is only closed when the breechblock is entirely closed, or so nearly closed that there is practically no difference. Power for the firing circuits is supplied at 25 volts from a motor generator set in the electrical platform, and the firing circuits are connected to the mains from the motor generator at the double-pole switch in the left-hand wing girder space just under the traversing-gear control stand. Four firing pistols are provided, Plate 180, one for each gun, at both right and left hand traversing control stations. Each pistol is connected to the mains by a knife switch, which must be closed to make the pistol operative. Suppose, for instance, that the right-hand traversing control station is being used and the guns are being fired separately, then both knife switches for the pistols in the right gun compartment would be closed and both switches in the left gun compartment would be open, and the switch boxes in the left compartment would be closed and locked to prevent any tampering with the switches. As the guns are to be fired separately, the knife switch connecting junction boxes Nos. 2 and 3, Plate 180, would be open and the box locked. If it is desired to fire the guns in *salvo*, the knife switch between junction boxes Nos. 2 and 3 must be closed and the knife switch closed for whichever firing pistol it is desired to use. The firing pistols for each gun are arranged in the same relative position as the guns; that is, when looking forward the switch for the right gun is on the right and that for the left gun is on the left. Two sockets are, however, provided for each firing pistol; one pair is arranged so that the pistol grips are in a convenient position for the man who is controlling the traversing handwheel to fire the guns. The second pair of sockets is placed forward of the first pair and reverses the direction of the pistol grips so that, if desired, a man can be located forward of the gun pointer and who can fire the guns on command from the gun pointer.

382. *Recoil mechanism.*—The recoil mechanism comprises a single recoil cylinder carried in the bottom of the cradle at the center, Plate 181. This cylinder is shown in detail on Plate 182. The

PLATE 180.



LENGTHS IN FEET OF BRANCHES OF FIRING CIRCUITS AND NO OF STRAPS, PLUGS, RECEPTACLES, JUNCTION BOXES, SWITCH BOXES AND PISTOL BRACKETS		DRAW NO
PRIMER TO JUNCTION BOX NO 1 - LEFT GUN FEET	43	11-6-332
PRIMER TO JUNCTION BOX NO 2 - RIGHT GUN FEET	43	11-6-332
JUNCTION BOX NO 1 TO FIRING PISTOL - LEFT GUN FEET	10.5	11-6-332
JUNCTION BOX NO 2 TO FIRING PISTOL - RIGHT GUN FEET	10.5	11-6-332
FIRING PISTOL TO S.B. NO 1 - LEFT GUN FEET	5.5	11-6-332
FIRING PISTOL TO S.B. NO 2 - RIGHT GUN FEET	5.5	11-6-332
S.B. NO 1 TO JUNCTION BOX NO 3 - LEFT GUN FEET	13.5	11-6-332
S.B. NO 2 TO JUNCTION BOX NO 4 - RIGHT GUN FEET	11.0	11-6-332
JUNCTION BOX NO 3 TO MOTOR GENERATOR SWITCH FEET	4.0	11-6-332
JUNCTION BOX NO 4 TO JUNCTION BOX NO 3 FEET	31.0	11-6-332
JUNCTION BOX NO 1 TO FIRING PISTOL - LEFT GUN FEET	42.0	11-6-332
JUNCTION BOX NO 2 TO FIRING PISTOL - RIGHT GUN FEET	42.0	11-6-332
FIRING PISTOL TO S.B. NO 4 - LEFT GUN FEET	8.0	11-6-332
FIRING PISTOL TO S.B. NO 3 - RIGHT GUN FEET	8.0	11-6-332
S.B. NO 4 TO JUNCTION BOX NO 4 - LEFT GUN FEET	3.0	11-6-332
S.B. NO 3 TO JUNCTION BOX NO 3 - RIGHT GUN FEET	6.0	11-6-332
GROUND TO MOTOR GENERATOR SWITCH BOTH ENDS FEET	3.0	11-6-332
JUNCTION BOX NO 2 TO S.B. NO 5 FEET	34.0	11-6-332
S.B. NO 5 TO JUNCTION BOX NO 1 FEET	7.0	11-6-332
STRAP - P45R - SINGLE	20	14-5-45
STRAP - P45Q - DOUBLE	17	14-5-45
STRAP 332D - TRIPLE	3	11-6-332
STRAP 332E - QUADRUPLE	11	11-6-332
PLUG - P45T1	36	14-5-45
RECEPTACLE - P45P1	36	14-5-45
GROUND CONNECTION - P45P	1	14-5-45
JUNCTION BOX AND COVER - FOUR WAY 331 B1 NOS 1, 2 AND 3	3	11-6-331
JUNCTION BOX AND COVER - THREE WAY 331 C1 NO 4	1	11-6-331
PISTOL BRACKET 332 F	3	11-6-332
PISTOL BRACKET 332 G	3	11-6-332
PISTOL BRACKET 332 A AND 332 B	2	11-6-332
WIRE FOR WINDING CONDUITS TOGETHER	[illegible]	11-6-332
CONTACT FORK CONNECTION - P45Z1 ON GUN	2	14-5-45
FIRING PISTOL P 39	4	14-5-39
NO. OF TAP BOLTS FOR STRAPS - 332 C	75	11-6-332
SWITCH BOX - 331A2 - NOS 1, 2, 3, 4 AND 5 WITH PADLOCK AND TWO KEYS EACH	5	11-6-331
MANTLET BRACKETS FOR SWITCH BOXES NOS 2 AND 3 - FURNISHED BY N.N.S.B.&D.D.CO	2	11-6-663
MANTLET BRACKETS FOR PISTOL BRACKETS - FURNISHED BY N.N.S.B.&D.D.CO	8	11-6-663
MACHINE SCREWS - .5X1 (C SUNK) FURNISHED BY N.N.S.B.&D.D.CO	4	11-6-663
NO. OF TAP BOLTS FOR BRACKETS - .5X1 - P45K	32	14-5-45
NO OF TAP BOLTS FOR BRACKETS - .5X1.375 - 332 C	32	11-6-332
NO OF TAP BOLTS FOR BRACKETS - .375X1 - FURNISHED BY N.N.S.B.&D.D.CO	12	11-6-663
STUFFING TUBES - LONG - FURNISHED BY N.N.S.B.&D.D.CO	6	11-6-663
STUFFING TUBES - SHORT - FURNISHED BY N.N.S.B.&D.D.CO	20	11-6-663
SPLIT WASHERS FOR GLANDS ABOVE NIPPLES - FURNISHED BY N.N.S.B.&D.D.CO	26	11-6-663
CORSET LACE PACKING FOR STUFFING TUBES - FURNISHED BY N.N.S.B.&D.D.CO	1 LB	11-6-663

NUMBER OF PARTS ORDERED IS FOR ONE TURRET

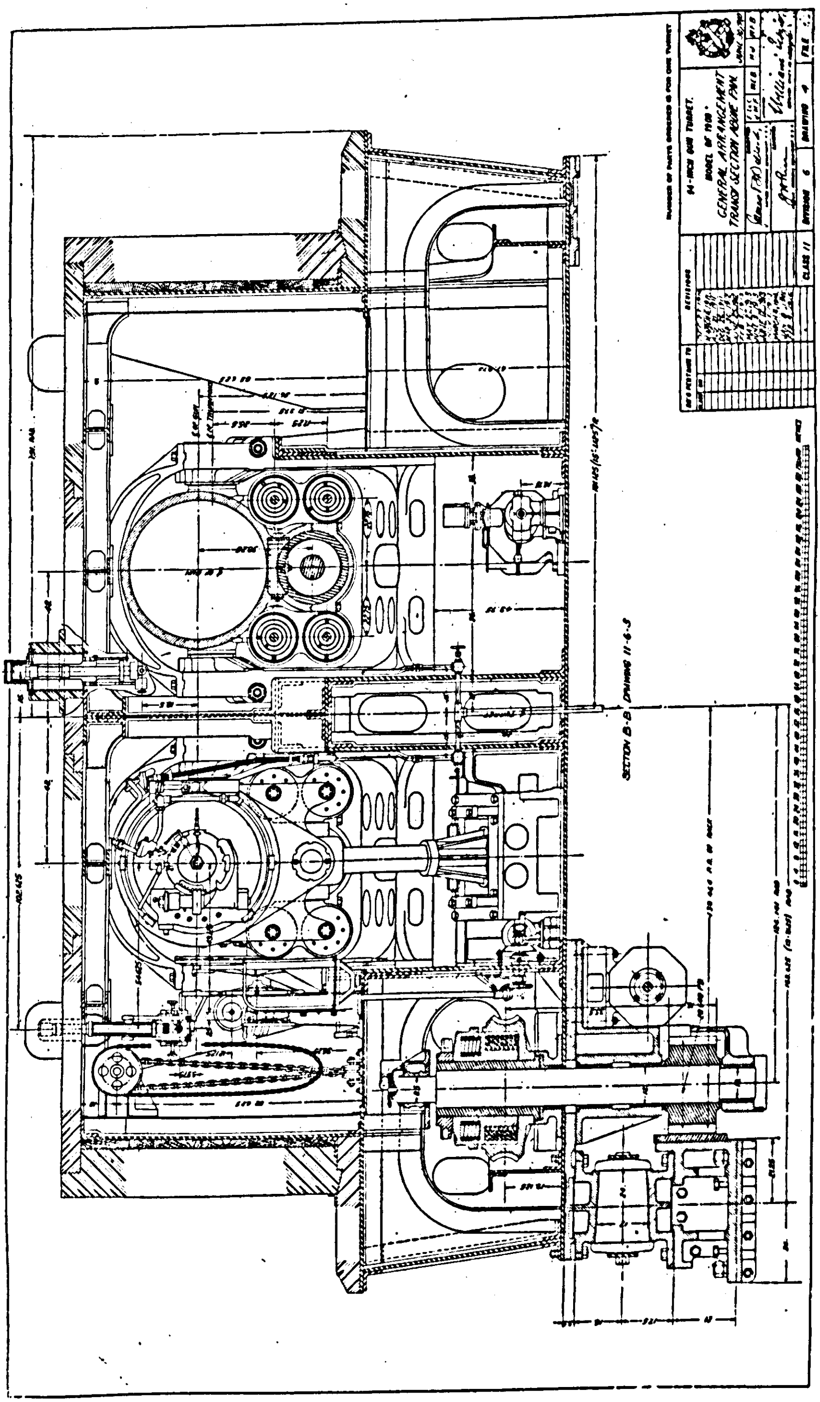
14-INCH GUN TURRET
MODEL OF 1909
FIRING CIRCUITS
DIAGRAM AND SPECIFICATIONS

JUNE 30, 1910

REVISIONS: APR 22 1911; FEB 5, 1916

CLASS 11 | DIVISION 6 | DRAWING 332 | FILE

PLATE 181.



maximum length of recoil is 48 inches and the pull on the piston rod correspondingly great, both because of the relatively short recoil and the single cylinder. The counter-recoil buffer is of the type so commonly found on practically all of our larger carriages—that is, a plug fastened to the cylinder head and entering a recess in the piston rod. In this case the buffer is approximately two-thirds of the total length of the cylinder. The void chamber is fastened to the cradle and connected by a brass pipe to the front end of the recoil cylinder. The cylinder is provided with three grooves through which the oil passes around the piston as the piston is drawn to the rear in recoil. The usual design prevails in the piston rod and piston. The piston rod is of forged steel, shaped on the forward end to a partial head onto which a bronze bushing is screwed and keyed, making the head complete and thereby furnishing the required different metal to slide in contact with the steel cylinder.

383. *Recuperator mechanism.*—The recuperator, Plates 181–182, comprises four spring cylinders, each of which is made up of a triple column of helical springs of round section divided into seven sections or groups along the spring rod. These four cylinders are attached by means of the necessary clips and rings to the cast-steel cradle, and the spring rods to the recoil lug on the breech end of the gun. These spring cylinders are shown on Plate 183. The four spring cylinders exert a sufficient pull to return the gun to battery at its maximum elevation of 15 degrees. In the event that these same guns be provided with any greater elevation it is probable that either additional spring cylinders will have to be provided or air cylinders may be substituted, since these cylinders would not be capable of returning the gun to battery at much greater elevations.

384. *Elevating mechanism.*—The elevating mechanism complete may be said to comprise the cast-steel yoke, mentioned before as connecting the side frames of the carriage and providing the bearing for the trunnions of the cradle, together with the elevating mechanism proper, comprising the single screw, nut, and train of gears and shafting leading to the handwheels and through the Waterbury speed mechanism to the electric motors. The yoke is a steel casting which extends between the gun girders for each gun and supports the trunnions of the cradle. It is made in two pieces for convenience in manufacture, but it is not necessary to separate these before assembly to the turret. The yoke strut extends over the cradle and acts as a brace for the yoke. This piece must be removed when the cradle is assembled to the yoke. It is desirable for the axes of the trunnion bearings of the two yokes in the turret to be in the same horizontal straight line, and in order to accomplish this the surfaces of the gun girders which bear against the yokes must be accurately finished and

PLATE 182.

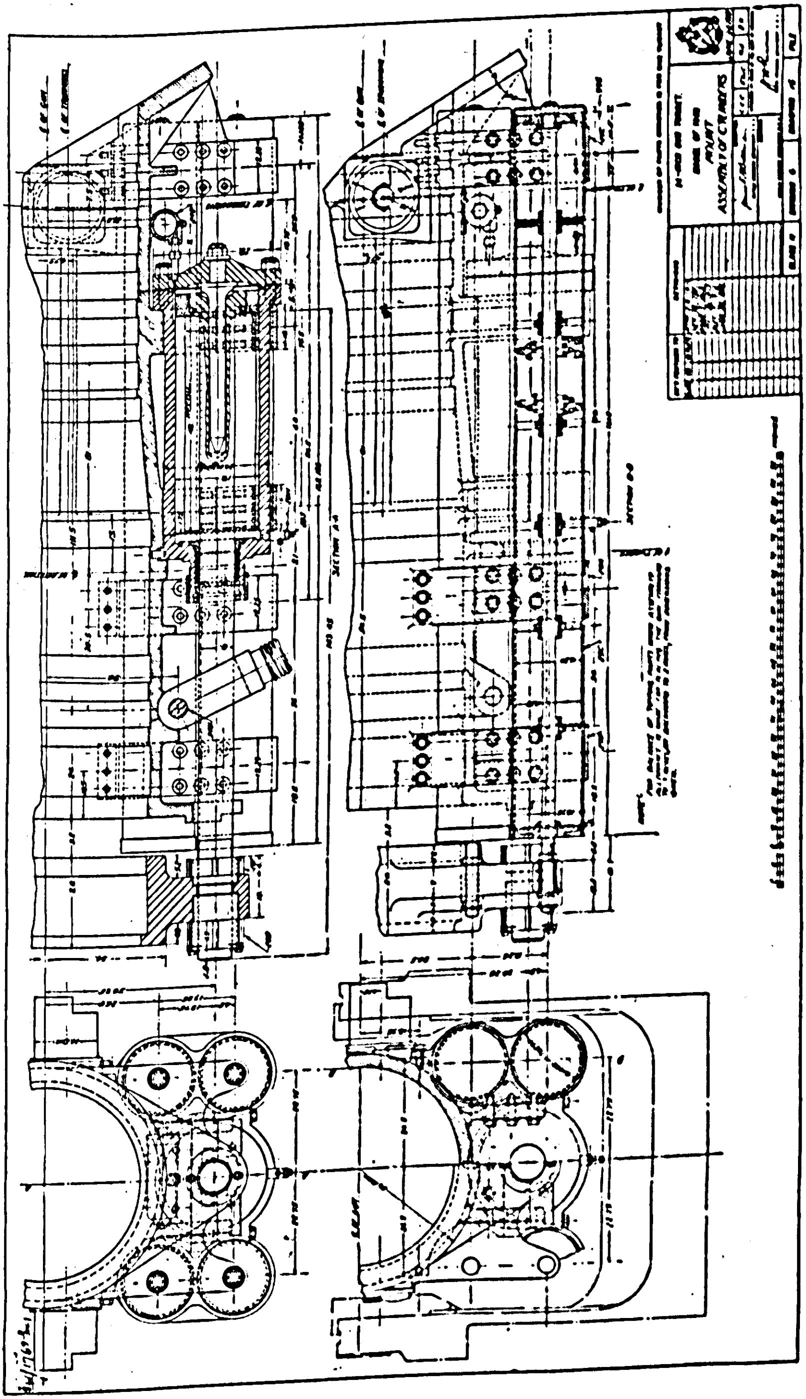
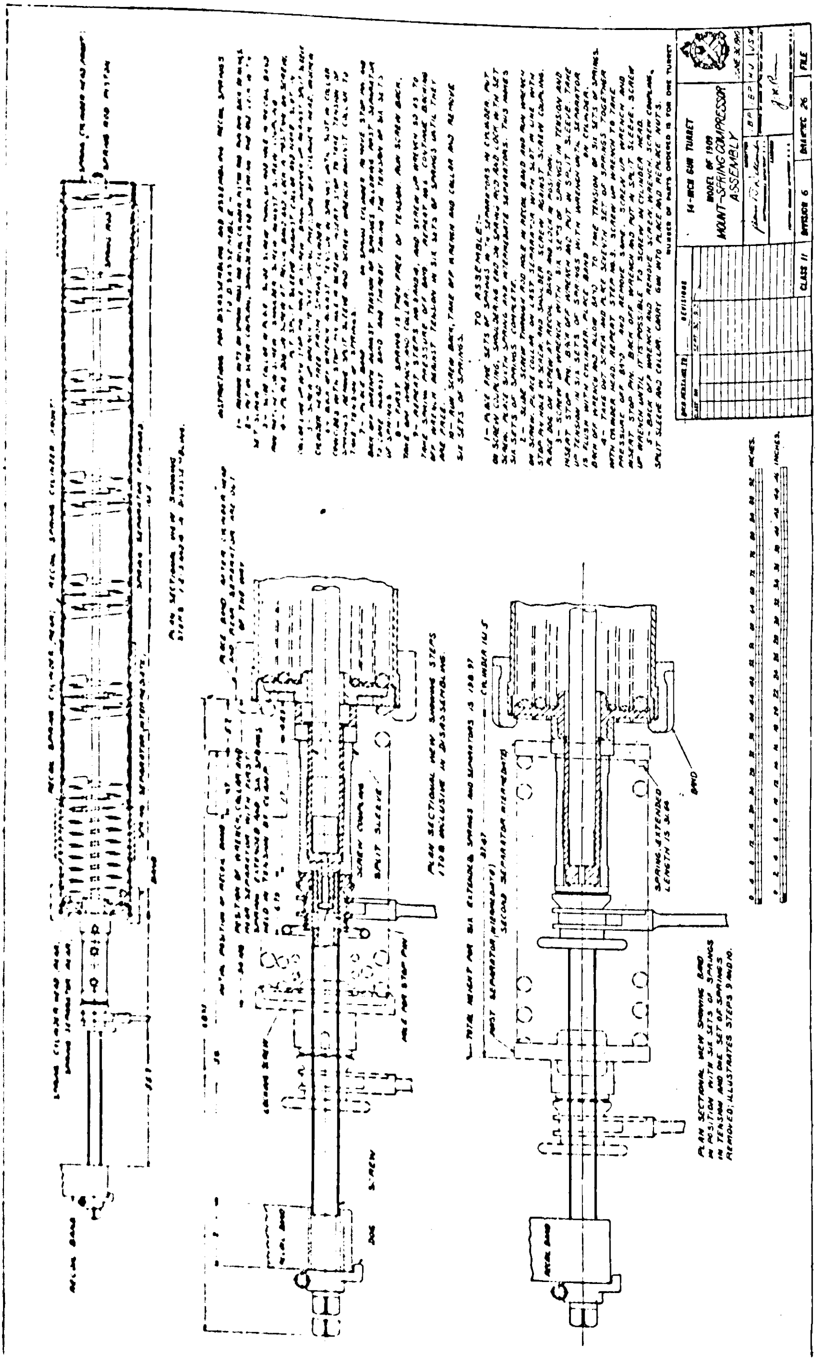


PLATE 183.



checked by straightedges laid across the turret. The bearings for the trunnions are spherical, and on the outboard side there are two eccentric bronze bushings which can be rotated with respect to each other, Plate 184, thus permitting the axis of the outboard trunnions to be moved not concentric with the position in the bearing yoke. The inboard bearing consists of a single concentric bronze bushing with a spherical seat in the yoke, Plate 185. The outer and inner eccentric bushings are secured so that they can not move from any fixed position by means of teeth on their outer ends which engage in the inner (29E) and outer (29L) locks. The inner eccentric bushing is retained in place by the inner eccentric ring (29M). In order to minimize friction when elevating or depressing the gun, the trunnion bearings are so arranged that the trunnions can be raised just clear of the main bearing by means of the wedges (32N) and (32M), operated by the differential screws (32A). A stud (32D) is inserted in the end of each trunnion of the cradle and rests on the trunnion float (32F). Each float rests on 16 steel rollers (32C), supported by the upper wedge (32N). The trunnions of the cradle have a clearance of 0.02 inch in the trunnion bushings, and when the lower wedge (32M) is drawn to the rear by the differential screw, the upper wedge (32N) is forced upward. The positions of the wedges are adjusted so that the trunnions of the cradle are lifted just clear of the trunnion bushings. The trunnions will then be supported entirely by the trunnion floats (32F), and when the cradle is elevated or depressed these trunnion floats will move forward or backward on the roller bearing; thus rolling friction is substituted for the sliding friction, which would occur if the trunnions rested entirely on the bushings. Care is taken to see that the trunnions are not raised sufficiently to bear on the top element of the bushings. A torque of about 16,000-inch pounds is required on the differential screw to lift each trunnion, and one revolution of the differential screw will lift the trunnion slightly more than 0.002 inch.

385. The elevating mechanism, Plates 186–187, consists of a single screw (32E), Plate 186, attached to the rear end of the cradle and working in a bronze nut (35A) supported by a bracket (38A), which in turn rests on structural beams extending between the outer and inner gun girders. The nut (35A) is connected by means of a suitable shaft and gearing so that it can be operated either by handwheel (44A), Plate 187, on the turret floor or by a variable-speed device driven by a motor. The speed of this device is controlled by a small handwheel (53N) located near the range dial and connected in the spindle of the variable speed gearing by a wire rope. The clutch operated by the handle (48A), located near the handwheel, is provided for changing the drive from power to hand, and vice

PLATE 184.

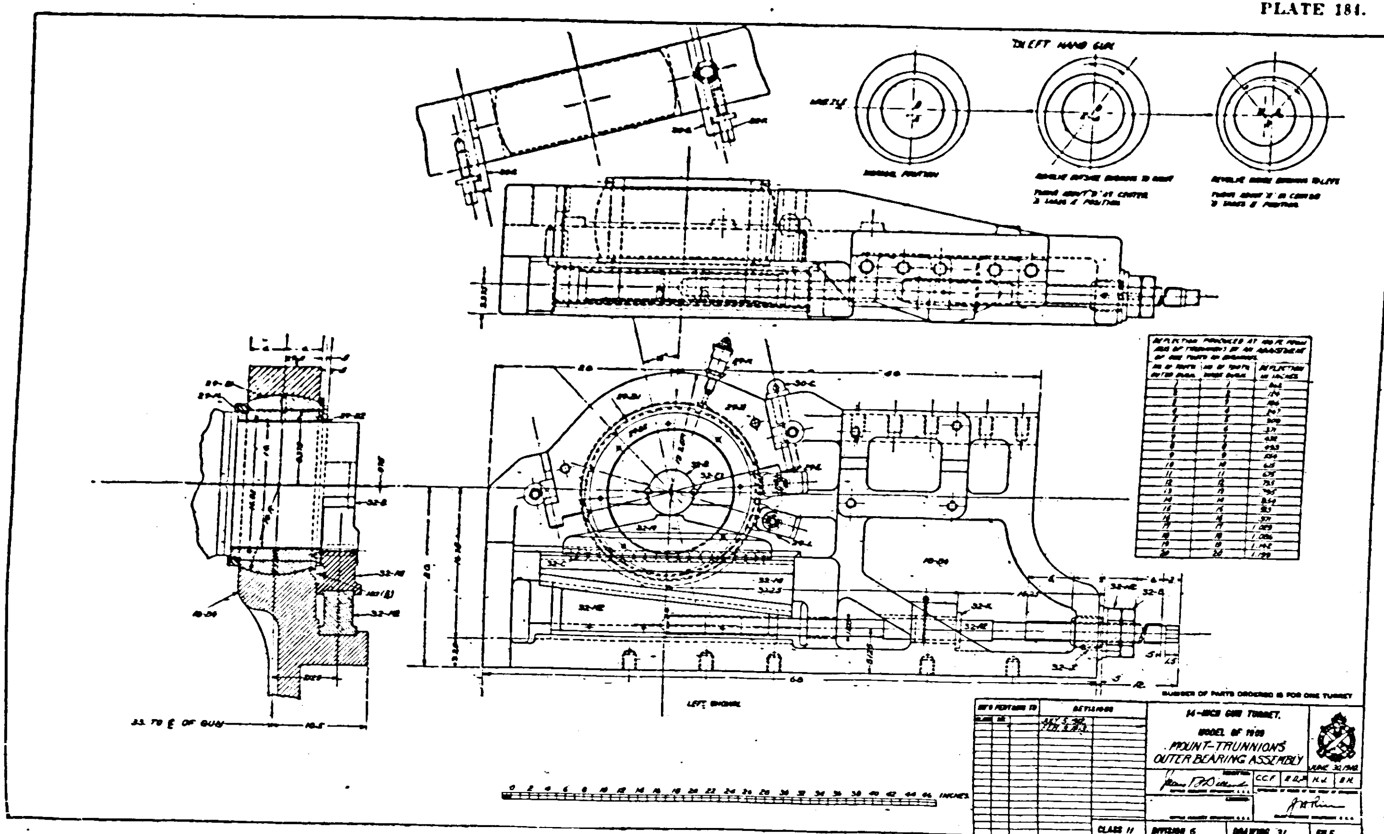

LEFT HAND GUN
NORMAL POSITION
NUMBER OF PARTS ORDERED IS FOR ONE TURRET
14-INCH GUN TURRET.
MODEL OF 1909
MOUNT-TRUNNIONS
OUTER BEARING ASSEMBLY
CLASS 11
DIVISION 6
DRAWING 31
FILE
INCHES
33. TO ℄ OF GUN

PLATE 185.

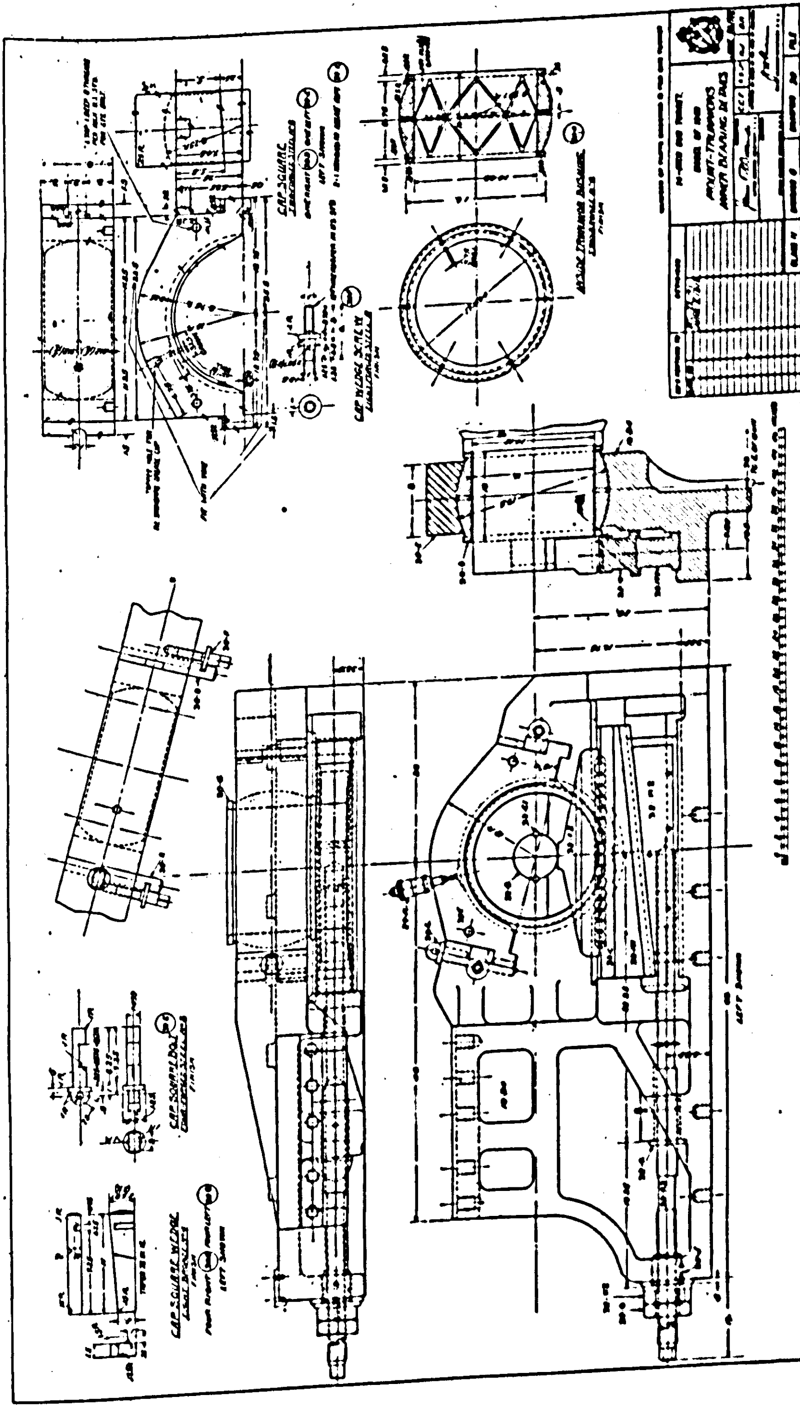


PLATE 186.

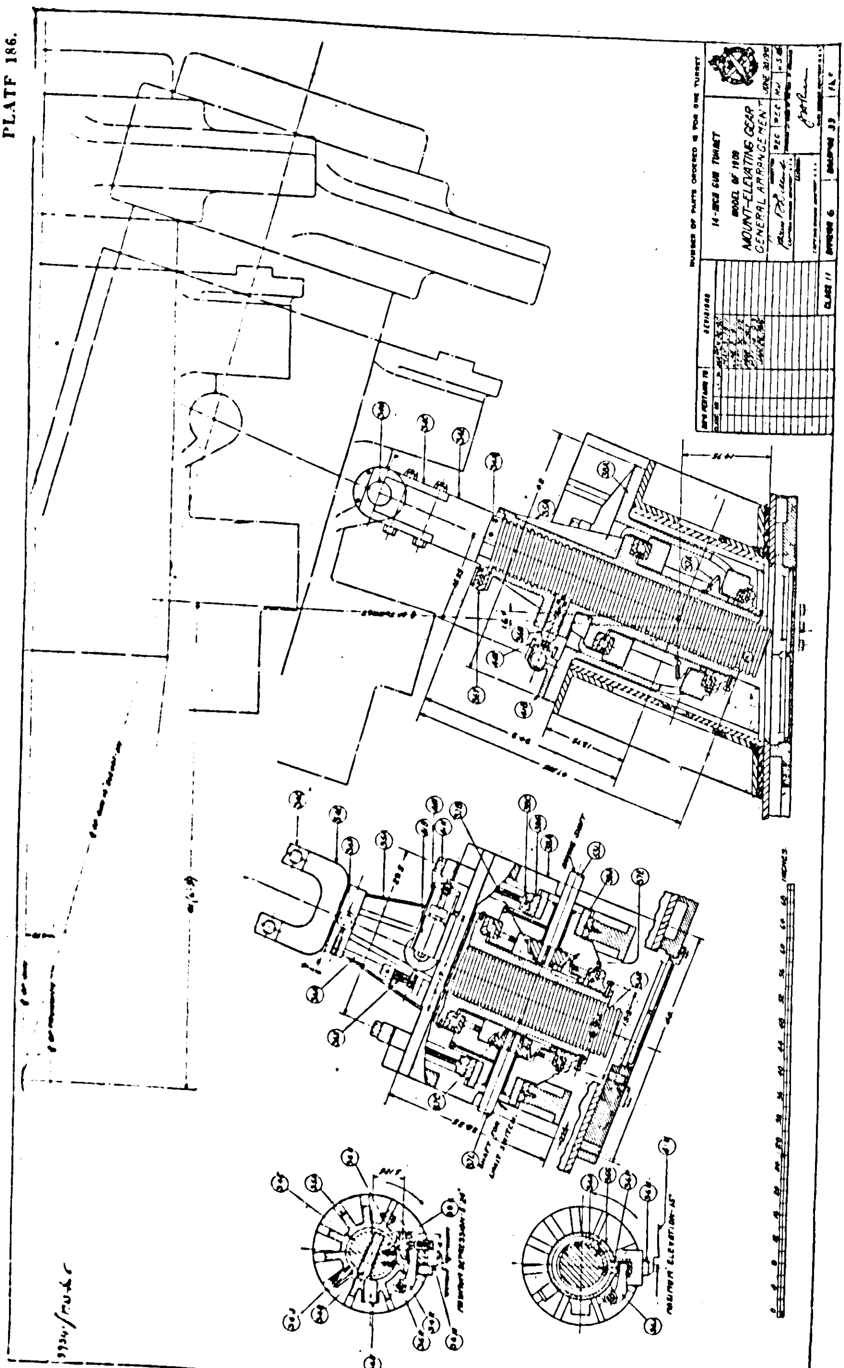
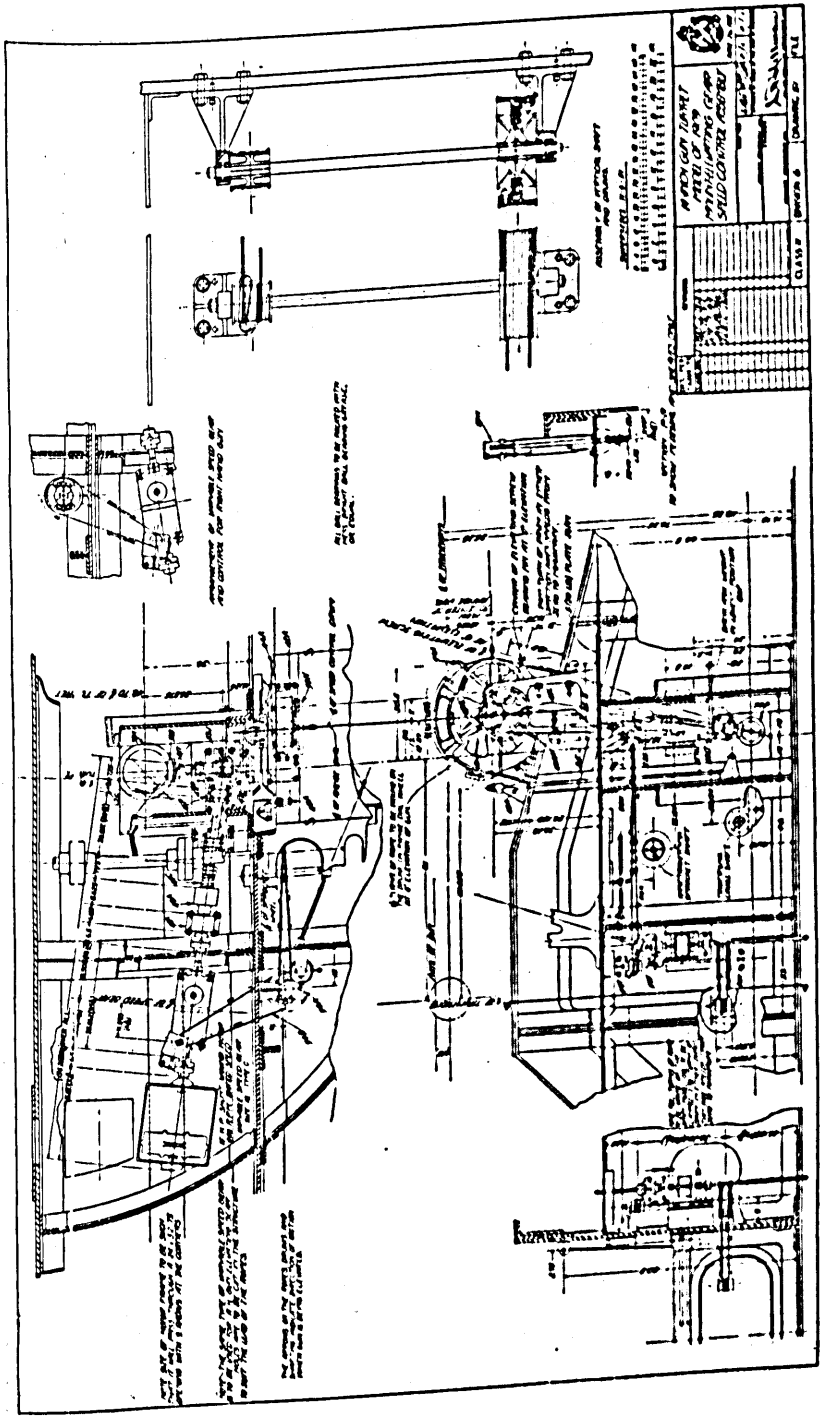

NUMBER OF PARTS ORDERED IS FOR ONE TURRET
14-INCH GUN TURRET
MODEL OF 1909
MOUNT-ELEVATING GEAR
GENERAL ARRANGEMENT
REVISIONS
CLASS 11
DIVISION 6
DRAWING 33
INCHES

PLATE 187.



versa. The range disk is supported by a bracket on the outer gun girder and is actuated by a rack attached to the cradle. The limits of elevation permitted by the carriage are from 5 minutes 24 seconds of depression to 15 degrees elevation. The principal parts of the elevating mechanism are the elevating screw; the elevating nut; the oscillating crosshead; the transom; the hand-operating gear; the power-operating gear, with the hand control therefor; the pedestal, which supports the operating handwheel; the range-dial wheel; the range-dial frame; the rack bracket; and a counterweight, which takes up the backlash between the rack bracket and the range-dial frame. The elevating screw has a single right-handed thread 1.25 inch pitch and 8-inch pitch diameter. It is attached to lugs cast on the rear end of the cradle by means of the elevating screw bearing pin (34U), Plate 186. The elevating nut (35A) is operated by the bevel gear (37A), and is supported on the oscillating crosshead (37E) by the upper and lower annular ball bearings. In order to prevent the elevating screw from being run up out of the nut when the gun is depressed, or to prevent the screw from being jammed down into the nut when the gun is being elevated, positive automatic stops are attached to the elevating nut which limit the elevation and depression of the gun. The elevation stop limits the elevation of the gun to 15 degrees and operates as follows:

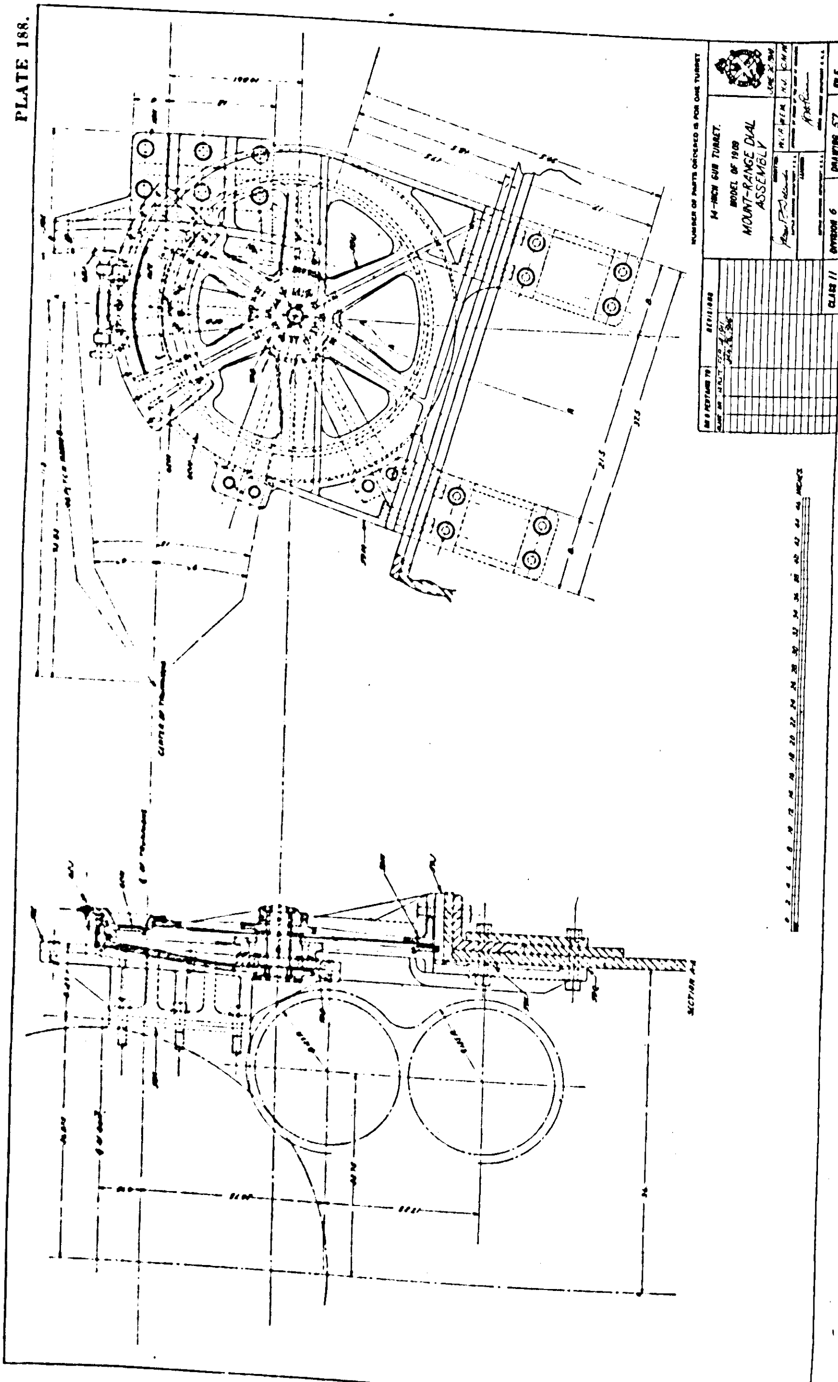
386. A cam (34A), Plate 186, is bolted to the upper end of the elevating screw, and when the gun has reached its maximum elevation it strikes the upper stop (366), which is bolted to the elevating nut. In the meanwhile the roller (36P) bears on the upper cam (34A) and forces the plunger (36Y) upward. This rotates the shaft (36R) against the action of the spring (36X), which in turn forces the plunger (36M) upward and causes it to engage the stop on the buffer yoke (41M). This buffer is provided for the purpose of easing the shock to the mechanism which would otherwise be caused by the abrupt action of the stops. The buffer has a stroke of about 1.5 inches in either direction, and consists of the buffer cylinder (41B), the piston shaft (41H), the buffer yoke (41M), and the necessary springs, stuffing boxes, and filling plugs. It is filled with hydrolene oil. The depression stop limits the depression of the gun to 5 minutes 24 seconds. The oscillating crosshead (37E) supports the elevating screw by means of two annular ball bearings, and is in turn supported by its trunnions, which rest in bearings in the transom (38A). The elevating motor, Plate 187, is shunt wound and rated at 15 horsepower at 400 revolutions per minute. It actuates the elevating mechanism through a Waterbury hydraulic variable speed gear, size 10, type "C," through a self-aligning coupling. The speed gear is in turn connected by a second self-aligning coupling and a friction clutch to the motor shaft gear (47M). The

power is then in turn transmitted through the clutch shaft gear (46L), Plate 187, elevating pinion shaft (53L), Plate 186, elevating bevel pinion (37B), and bevel gear (37A), which is keyed to the elevating nut (35A). The friction clutch comprises alternate disks of bronze and steel, the bronze disks being keyed to the friction coupling disk cup (49A), Plate 187, and the steel disks to the friction coupling shaft (49C). This clutch is provided to ease the shock on the motor and mechanism when the elevating screw is brought up against the maximum or minimum stops which limit the elevation of the gun to 15 degrees and depression to 5 minutes 24 seconds. The stops are strong enough to stop the elevating screw without injury to any other parts when the gun is being elevated and depressed at full speed. They are, of course, provided for emergency only.

387. The switch shaft handle (48A), Plate 187, operates the clutch so that the elevating screw may be connected for hand or power operation, or may be disconnected entirely. The bevel gear (44G) runs loose on the shaft (53J) and is connected to the elevating handwheel (44A). The bevel gear (47L) also runs loose on the shaft (53J) and is connected to the elevating motor. The elevating gear clutch (53H) is keyed to the shaft (53J) and is made to slide on the shaft longitudinally by the mechanism connecting it with the handle (48A). With the handle in the position marked "Motor," the claws of the clutch are engaged with the claws of the bevel gear, and the shaft is compelled to turn with the gear. When the handle is in the position marked "Hand," the claws of the clutch (53H) are engaged with those on the gear (44G), and the shaft (53J) is compelled to turn with that gear. With the handle in the position marked "Off," the clutch (53H) is not engaged with either of the gears (44G–47L), and the elevating screw can not be operated by either the hand or motor driven apparatus. When the mount is not being used for drill or otherwise, the handle (48A) should be in the "Off" position, and the handwheel (43N) should be in the neutral position. The average force on the handwheel to elevate or depress the gun by power will vary from 15 to 20 pounds with all parts of the control apparatus in good condition. The force on the handwheel required to elevate or depress the guns by hand varied from 50 to 125 pounds, depending on whether the guns are loaded or unloaded, and whether or not the trunnions of the cradle are resting on the floating trunnions. Care is taken in assembling the rubber gasket of the gun port seal, Plate 178, for if this gasket is too tight the friction between it and the sides of the opening very materially increases the force required to elevate or depress the gun.

388. The elevation disk (60N), Plate 188, consists of a German-silver ring fastened to the dial wheel (58U). The dial wheel runs free on a shaft supported by the bracket (59M) which is attached to

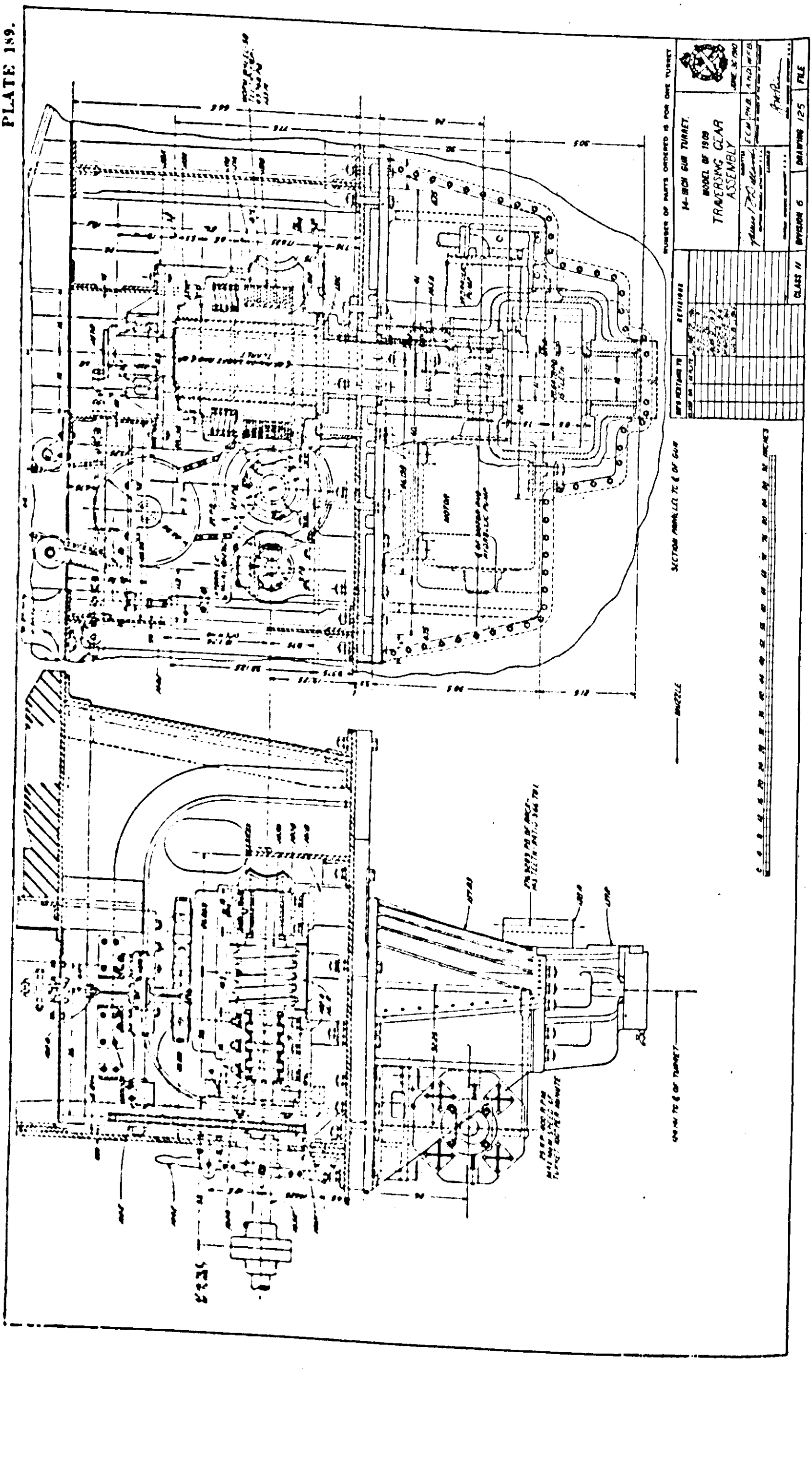
PLATE 188.


14-INCH GUN TURRET.
MODEL OF 1909
MOUNT-RANGE DIAL
ASSEMBLY
SECTION A-A
CLASS 11
DIVISION 6
DRAWING 57
PLATE 57
INCHES

the outer gun girder. The pinion (58B) is bolted to the dial wheel and engages in the rack (58E). The rack is attached to the bracket (58K) which is bolted to the cradle, and as the gun is elevated or depressed the rack actuates the pinion, thus turning the dial wheel. The blacklash between the rack and the pinion is taken up by a counterweight, which is connected to the dial wheel by means of a wire rope. The German-silver ring (60N) has three sets of graduations; those on the outer circumference being for the service range scale; those on the inner circumference being the subcaliber scale, and between these, degree marks are stamped for use in checking up the other scale by means of a clinomenter. The degree marks are placed on the disk with the gun mounted on the carriage, the clinometer being supported by a rest placed in the muzzle of the gun. The degree marks may be put on the disk at the time of the shop test, but the location of the service and subcaliber scales are dependent upon the height at which the gun is mounted above the sea level and must be located after the gun is mounted in the fortifications. The pointer for the service scale and that for the subcaliber scale are mounted on the window (62M) and bear respectively on the outer and inner circumferences of the range scale. The position of the window, and consequently of the pointers, may be adjusted by means of the worm shaft handle (62J) for purposes of calibration. In order to indicate the movement of the window for this purpose, the outer index plate (62E) is attached to the window and bears on the plate (62D), which is bolted to the bracket (59M).

389. *Traversing mechanism.*—The principal parts of the turning gear are the upper and lower roller tracks, the base ring, the rollers, live ring, and the operating machinery. The operating gear consists essentially of 2 pinions carried by the rotating part of the turret and gearing into a rack bolted to the base ring, Plate 181. The pinions are supported by castings bolted to the structural members of the turret, and each is driven by a worm wheel and worm, Plate 189. The worms are interconnected and are driven by either of 2 Waterbury hydraulic speed gears, each of which is operated by a 25-horsepower electric motor. The variable speed gears are controlled by handwheels located at the sights and by a handwheel at the auxiliary traversing station in the upper handling room. The weight of the entire turret, except the loading table in the lower handling room, is borne by the base ring. The base ring is cast in four segments which are bolted and keyed together. In order to make a better joint with the concrete foundation, the undersurface of the base ring is checkered with projections 1 inch square. In addition to the small projections, radial ribs are cast on the undersurface of the base ring through which the holes for the anchor bolts are drilled. The anchor bolts are 3 inches in diameter and are

PLATE 189.



14-INCH GUN TURRET.
MODEL OF 1919
TRAVERSING GEAR
ASSEMBLY
CLASS 11
DIVISION 6
DRAWING 125
FILE
MOTOR
MUZZLE

fastened by lock nuts. Eighty-eight leveling screws are provided, which bear on the 44 leveling plates. Access holes are cast in the base ring through which the leveling screws and anchor bolt nuts can be reached by the ratchet wrench provided for that purpose. The lower roller track rests on the upper surface of the base ring and is cast in four main sections and 4 portable sections. The portable sections are provided for the purpose of enabling the traversing rollers to be removed. The traversing rack, which is in 8 sections, is bolted to the inner face of the base ring. The rack has 145 teeth. There are 32 traversing rollers, in each end of which a graphite bushing is pressed and fastened with lock screws. The traversing roller shafts are kept from turning by screw dowels engaging in a recess cut on the inside of the live ring. The live ring is built up of 8 inside sections of forged steel and 8 outside sections of forged steel, connected by 32 distance pieces of cast steel.

390. The upper roller track is cast in six sections of three different lengths and is bolted through the cast-steel liner to the pan bottom. The track liner is cast in six sections, two right, two left, and two side sections, right side and left side. The traversing motor controlled from the gun chamber operates the A or pump end of the variable speed gear, which is connected by two pipes to the B or engine end. The shaft of the engine end turns the traversing worm and worm wheel, Plate 189, by means of the pinion and gear. The turret is turned by either the right traversing motor or the left traversing motor; not by both together. Hand chains run over six hand chain wheels, keyed to a longitudinal shaft in each gun chamber. This shaft is supported by roller bearings and is furnished with universal joints to provide for a necessary angle in the shaft and faulty alignment. At the front end of each shaft is keyed a chain sheave connected by the large chain to the chain wheel; a chain tightener is provided for the chain. The chain wheel turns the small sprocket wheel through the shaft. The large sprocket wheel is connected to a small sprocket wheel by the roller chain. The large sprocket wheel runs free on the training gear cross shaft when the clutch operated by the hand-turning clutch lever is thrown "out." The variable speed gears on the right and left sides of the turrets are entirely independent of each other. However, by a suitable arrangement of clutches they may either one be controlled from any one of three handwheels located as follows: (1) Right side of turret chamber, (2) left side of turret chamber, (3) auxiliary control station in upper handling room. The speed of traverse of the turret varies from zero to 100 degrees per minute in either direction, and this variation is obtained by turning any

one of the handwheels from the zero position to 300 degrees clockwise or counterclockwise. The high turret may be turned continually in one direction, but the low turret can be turned a maximum of 115 degrees only from its zero position. After having been turned 110 degrees in either direction a cut-out lever in the front of the low turret operates to turn the control mechanism on the end of the variable speed gear to its neutral position. This cut-out, for its complete operation, requires the turret to turn from 110 to 115 degrees. The duplicate installation of power traversing gear is provided so that in case of accident to one mechanism the other will still be in service. The auxiliary control station in the upper handling room is provided in case it should be desired to point the turret by means of the azimuth scale located on the upper side of the traversing rack. In case both sets of power apparatus are not in working order, it will be necessary to resort to the hand-traversing gear. As stated above, the low turret is intended to be traversed 115 degrees on each side of the longitudinal center line of the fortifications. In order to automatically limit the movement at these points, a control rope for the low turret is led around a cut-off drum which is geared to a cut-off lever. At the limit of traverse in each direction the cut-off lever is engaged by the cut-off cams and is thrown to the neutral position so that the driving mechanism is stopped. The action of the mechanism is shown on Plate 190. This cut-off mechanism is omitted on the high turret, as it may be traversed continuously in either direction.

391. A speed indicator dial is located under each traversing handwheel in the turret chamber, and over the auxiliary control handwheel in the upper handling room. The dial is geared to the handwheel shaft and indicates to the turret trainer the approximate speed at which the turret is turning. It is graduated for one-fourth, one-half, three-fourths, and full speed in each direction. The zero plate must be located to read "zero" when the control shaft and the A end of each variable speed gear is in the neutral position. It is illuminated by an 8-candlepower lamp in series with the lamp for the azimuth indicator. The azimuth indicator gear, Plate 191, is provided for the purpose of enabling the pointer to lay the turret to a prescribed angular distance in azimuth either side of the emplacement zero and is used mainly for indirect fire. A beveled gear is rigidly attached to the upper end of the traversing shaft and is connected by horizontal and vertical shafts to the azimuth indicator case, located on the azimuth pedestal. The gearing in the case is arranged to turn two pointers over the indicator dial. The inner scale is graduated to 10 degrees and makes one revolution of the turret. The outer scale is graduated in tenths of degrees and makes

PLATE 190.

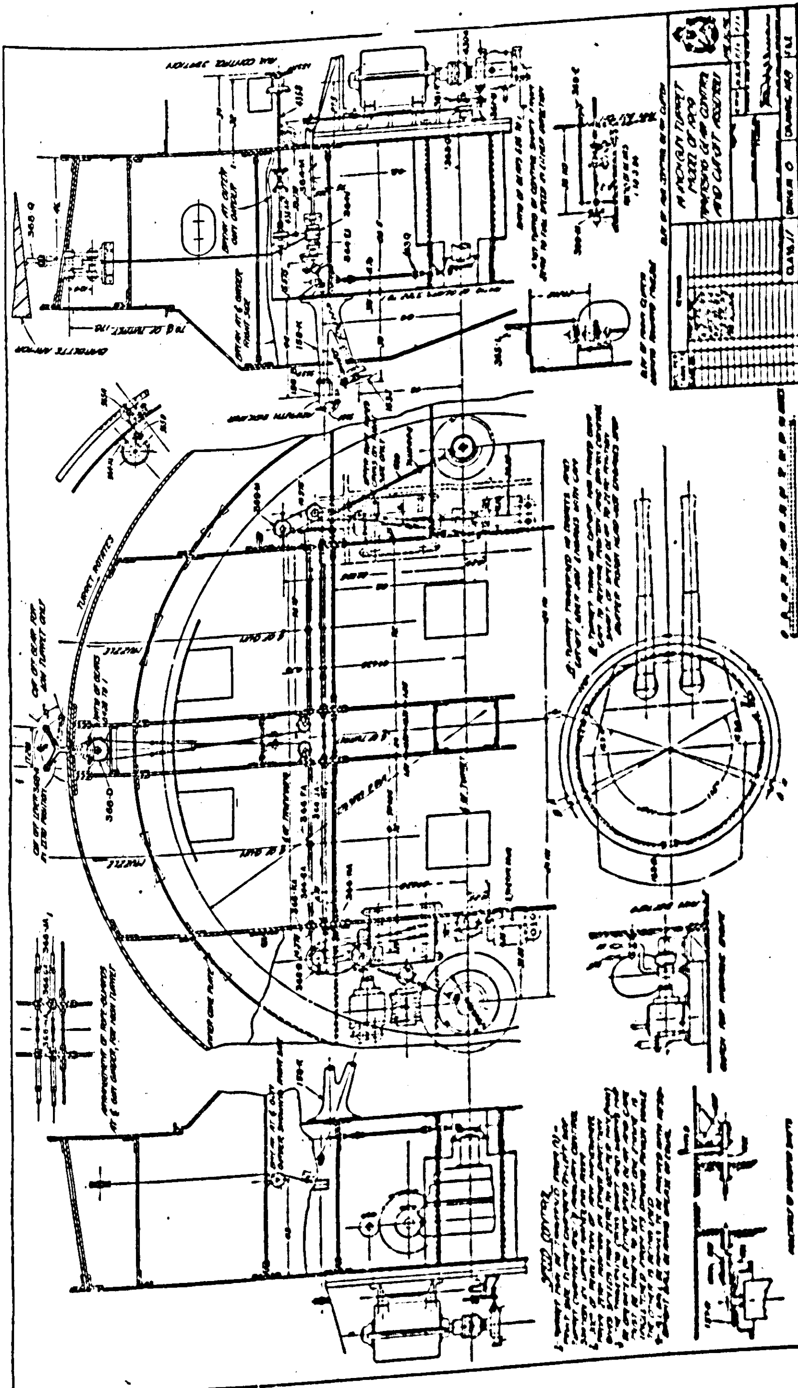
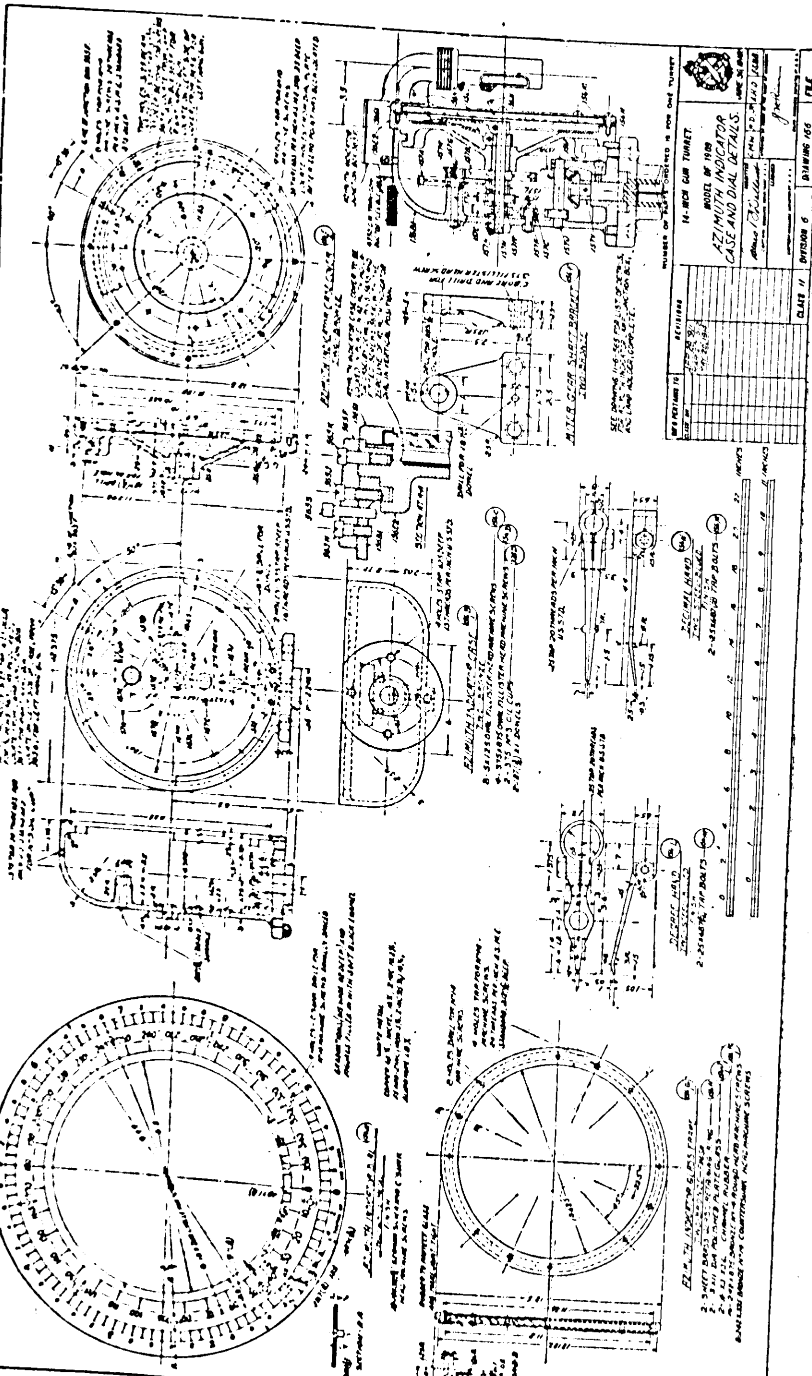


PLATE 191.


14-INCH GUN TURRET.
MODEL OF 1918
AZIMUTH INDICATOR
CASE AND DIAL DETAILS.
CLASS 11
DIVISION 6
DRAWING 166

one revolution for each 10 degrees traverse of the turret. It is illuminaed by an 8-candlepower lamp in series with a similar lamp for speed indicator. A brass azimuth circle attached to the top of the traversing rack is graduated in degrees, the numbers of which are to be added after the turret is erected in its emplacement. A hole is cut on the right side of the wall of the upper handling room through which access may be had to the azimuth pointer, which is carried by a bracket bolted to the track plating. The pointer is provided with a micrometer and subscale. The subscale has slotted holes to give it sufficient movement for adjustment, after which it is fixed in position by two dowels. It is graduated and stamped in decimals of degrees, the least reading being 0.1 degree. The micrometer scale actuating the pointer is graduated to a least reading of 0.01 degree. The hole in the trunk plating is provided with a sliding door, and a platform is so arranged as to support the person reading the azimuth scale.

392. *Loading mechanism.*—These guns are normally loaded by means of a mechanical rammer, Plate 178, which comprises a steel chain running over a sprocket (the rammer head being on the end of the chain), a chain case, and an electric motor. The links of the chain are so constructed that the chain can bend in only one direction. The chain is habitually coiled in a cast-steel chain case. When a projectile or a powder section is rammed the chain is run out of the case and, resting on the tray and the bottom of the bore, pushes the projectile to its seat. As the chain is supported by the tray and the bottom of the bore on the only side to which it could bend, it becomes a built-up column and is rigid. The length of stroke may be controlled, and as a safety precaution the last link is so constructed that it can not pass the sprocket. The three lengths of stroke in ramming the projectile, the first powder stroke, and the second powder stroke are, respectively, 14 feet 8.64 inches, 11 feet 2.98 inches, and 7 feet 6.78 inches. To prevent undue strain on the motor in case of a sudden check in the movement of the chain, a friction clutch on the motor shaft is provided; likewise, to lessen jar and wear and tear of service, buffers are provided for checking the movement of the chain upon being withdrawn after ramming. This rammer is driven by an electric motor through a sprocket, pinion, and chain. The chain is a Morse silent drive, approximately 20 feet long and is protected by a guard. A clutch is provided on the motor shaft to prevent undue strain in the event of too sudden check, such as would occur when the rammer has run out to the limit of its stroke and stops suddenly when the tail link chocks the chain sprocket. This is again the usual type of friction clutch comprising seven bronze and six steel disks, the pressure be-

tween the springs being maintained by a spiral spring and adjusted by means of a screw and nut. The mechanism provided for transferring the projectile from the storage rooms below to the tray at the breech of the gun is described under the heading "Ammunition supply system."

393. *Sights and observation.*—The 3-inch telescopic sight for the 14-inch gun turret, model of 1909, is a vertical telescope fitted with such an optical system that the gunner with his eye at the eyepiece may bring into the field of view an object and correctly lay the guns in azimuth. There are two sights installed in each turret and a spare sight for replacement. The principal parts are the telescope, cradle, carriage, sight brackets, deflection scale (front), deflection scale (rear), elevation worm, deflection worm, lamp cable, and electric lamps. The tube bearing (bottom) is attached to the lower end of the telescope and has three short finished surfaces on its perimeter. The tube bearing (top) is attached to the upper end of the telescope and has three short finished surfaces on its perimeter, and a hooklike projection. By the use of this hook the telescope is hung on the upper end of the cradle and locked in place by the telescope clamps. The trunnions of the cradle are seated in the bearings of the carriage and secured by the caps. The cradle arm riveted to the side of the cradle meshes with the elevation worm. By rotating the elevation handwheel the telescope can be brought to the desired elevation. Two deflection scales are provided for reading from either front or rear. The deflection scale (front) is attached to the sight bracket, and the deflection scale (rear) is attached to the carriage. Each deflection scale is retained by two screws which pass through elongated holes, permitting adjustment of the scale. The deflection scales are graduated in degrees. The numbers at each graduation are reference numbers and read from 1 to 5, 3 representing the origin or central position of the deflection scales. The deflection bracket (front) is attached to the carriage and has a line graduated near its lower edge which registers with the graduations on the deflection scale (front.) The deflection bracket (rear) is attached to the sight bracket and has a German-silver piece soldered to it, upon which a line is graduated. This graduated line registers with the graduations on the deflection scale (rear). Each deflection bracket has a receptacle for a small electric lamp. Through the openings in these receptacles rays of light from the lamps illuminate the deflection scales. All of the parts for the sights are interchangeable, except the sight brackets, which are right and left. The principal parts of the telescope are the telescope tube, objective prism holder, optical elements, cross wires, lamp bracket, draw tube, focusing nut, focusing nut cap, and the eye-

pieces. The cross wires are of platinum wire 0.001 inch in diameter. They are secured to the cross-wire frame by four cross-wire clips, and are at right angles to each other. The cross-wire frame is set on dowel pins in the cross-wire frame holder and is secured by the cross-wire frame clamp screw and may be removed by the cross-wire frame extractor, after removing the eyepiece and turning the cross-wire frame clamp screws 180 degrees. The cross wires are illuminated by a small electric lamp placed in the lamp bracket, which is secured to the rear end of the telescope tube. Two lamp-bracket reflectors, in the lamp bracket, deflect the rays of light through the openings and through the telescope tube and draw tube 90 degrees apart. These openings are so arranged that the light from each reflector is thrown upon the full length of the wire opposite. The intensity of illumination of the cross wires may be varied by turning the lamp-bracket adjusting nut, thereby varying the area of the light openings. In addition to the sights just described, each turret is provided with a periscope, model of 1909. This is an observation instrument and is located at the captain's station at the rear of the turret guns and on the periscope guard, Plate 178. One periscope is provided for each turret. The periscope for the high turrets is 9 inches longer than that for the low turrets. The principal parts of these periscopes are a telescope, cradle, hood, hood cap, shutter, elevation worm, azimuth worm, prism rectifying horizontal shaft, azimuth vertical shaft, lamp cable, and electric lamp.

394. *Armor.*—The armor for the protection of the turrets consists of the barbette armor, which is anchored in the concrete of the fortifications, and the turret armor, which is attached to the turret structure and rotates with it. The barbette armor is in the form of a cone with the sides inclined at an angle of 7 degrees 8 minutes to the vertical and projects 14 inches above the surface of the concrete. The total width of the barbette armor is 131.36 inches. The upper strake, about 84 inches wide, consists of seven pieces 18 inches thick, which are connected at the joints by steel keys 4½ inches square. The lower strake consists of five plates 8 inches thick, rabbeted into the upper strake, and connected at the joints by steel keys 2½ inches square. Each piece of the upper strake is anchored in the concrete by four anchor bolts extending in a direction perpendicular to the outer face of the plate. The front, side, and back plates are backed with about 3 inches of teak wood, and are fastened to the structure by steel tap bolts extending through the wood backing, the heads of these bolts resting against the inside of the armor backing plates. The shelf armor plates are fastened directly to the structure by tap bolts without wood backing between. The roof plates are fitted to the front, side, and rear armor plates and are fastened by countersunk steel bolts. The top armor is also connected to the roof girders

of the structure by tap rivets. The irregularities in the thickness of the front, side, and rear armor plates are compensated for by variations in the thickness of the wood backing. Similar variations in the shelf and roof plates are compensated for my inserting steel liners between the structure and the armor wherever necessary to give a good bearing surface. The rear armor plate is dovetailed into the rear side armor by a joint of such shape that the weight of the rear armor is supported by the rear side armor plates. In order to give a better support to the individual armor plates, the front and side armor plates are dovetailed into the shelf plates in the manner shown on Plate 181. Two hatches are cut in the roof armor for the purpose of allowing large parts, such as rammers, ammunition cars, etc., to be removed from the interior of the turret without disturbing any large armor plates. These hatches are covered by the roof hatch armor plates, which are attached to the roof armor by countersunk bronze bolts.

395. Two armor hoods are attached over openings in the roof armor for each turret. The sights extend through these openings and their upper ends are protected by the hoods, Plate 178. A similar hood is provided in the rear of each turret for the protection of the periscope. Shutters are provided inside the hoods of the low turret to exclude the blast from the guns of the high turret. One access hatch is cut in each rear shelf plate to give access to the turret from the outside of the fortification. These hatches are closed by 2-inch hinged hatch covers. A clearance of 4 inches is provided all around between the inside circle of the barbette armor and the outside circle of the shelf armor, and a vertical clearance of 4 inches is allowed between the under surface of the rear shelf armor and the top surface of the barbette armor. In order to exclude water, these clearance spaces are closed by the watershed. The watershed is designed to prevent the entrance of water through the clearance space allowed between the barbette armor and the shelf armor. The fixed part consists of a ring of structural plates attached to the edge of the barbette armor, from the outer edge of which is hung a piece of canvas with a galvanized-iron strip around its bottom. The rotating part consists of a circular ring attached to the shelf armor plates, supporting at its outer edge a channel and bronze strip which extends on the outside and under the canvas strip attached to the barbette. The joints of the rotating ring are calked where necessary to shed water, and water is prevented from entering at the side and underneath by the canvas strip. The construction at the rear of the turret is similar in principle.

396. *Ammunition supply system.*—The projectiles are picked up in the magazine by trolley hoists running on I beams which lead into the lower handling room. The I beams from the magazine are con-

PLATE 192.

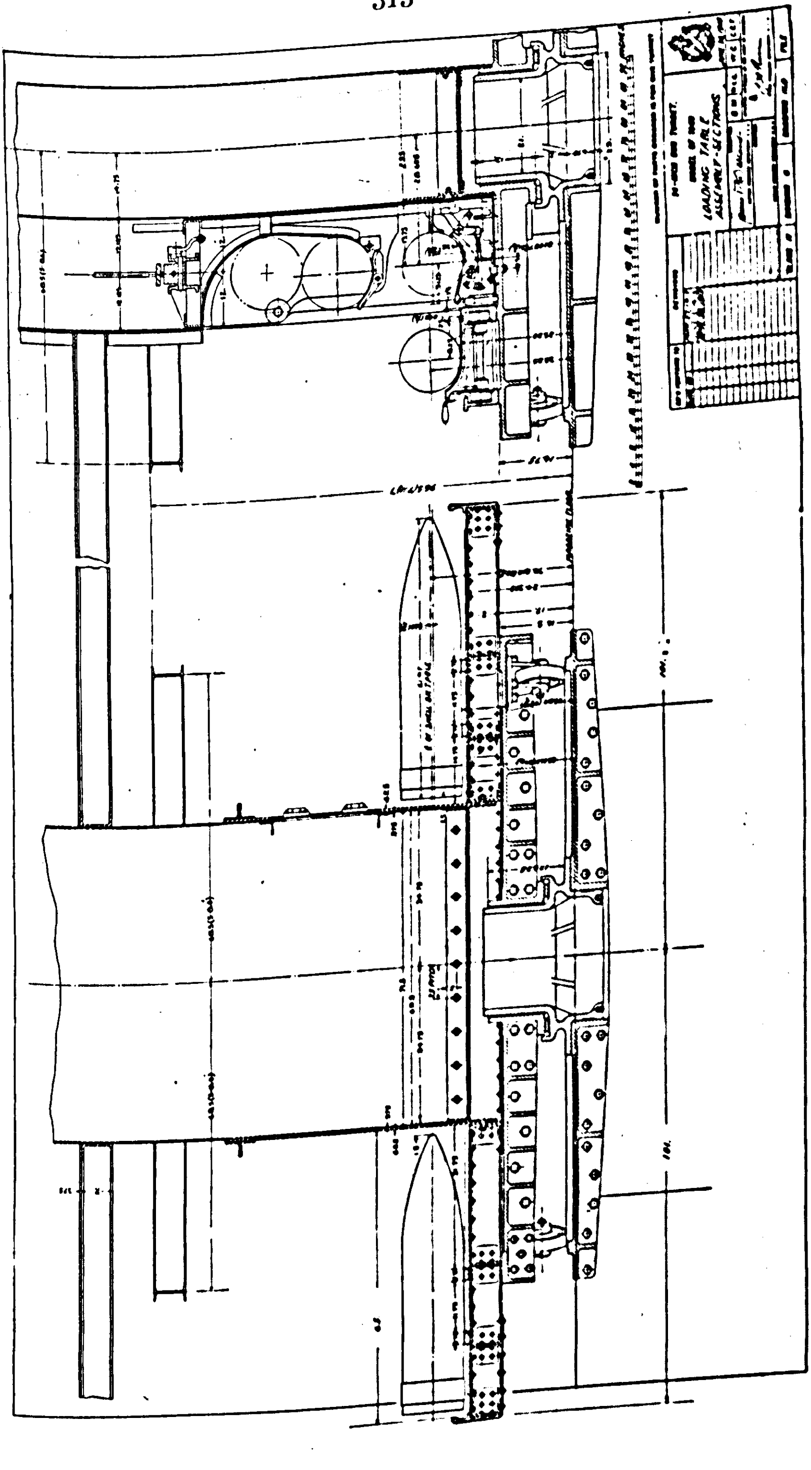


PLATE 193.

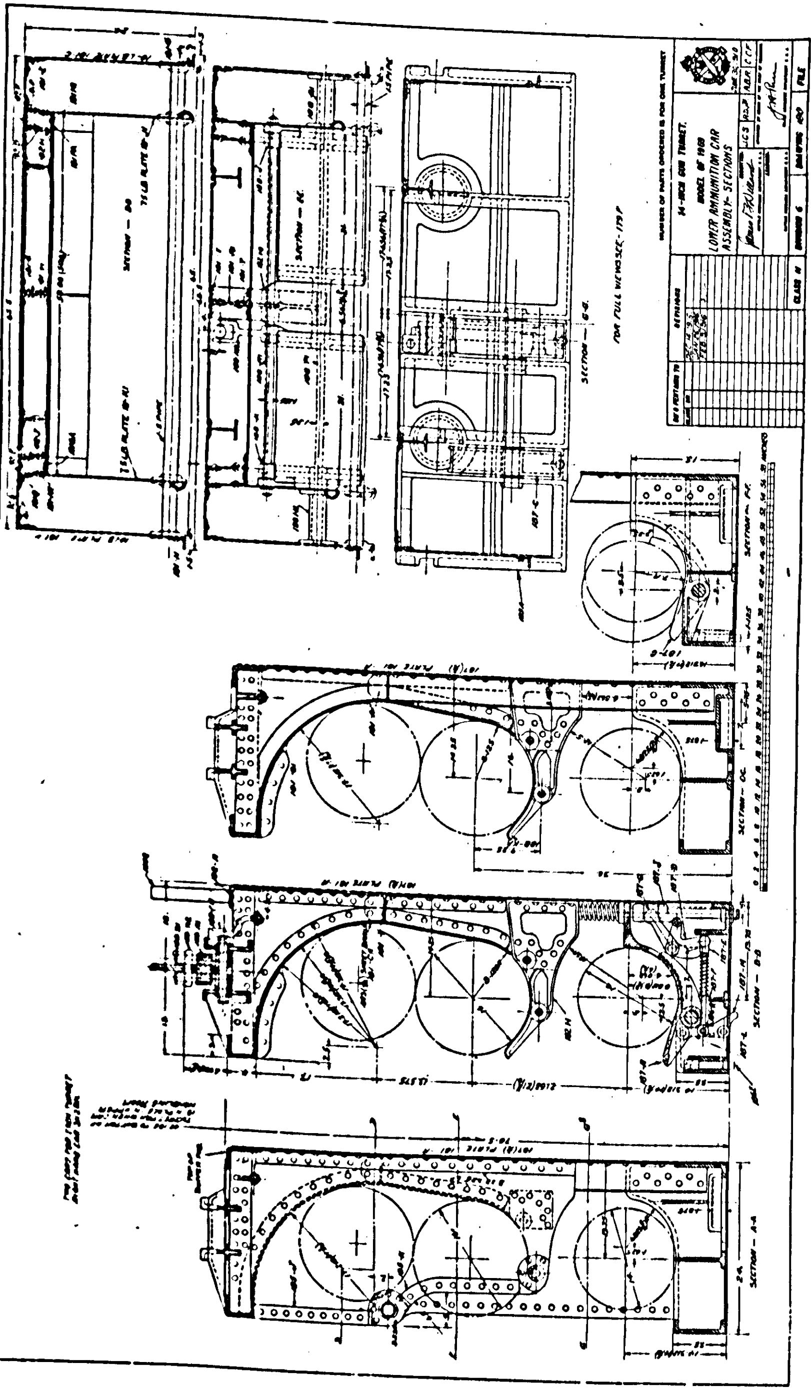
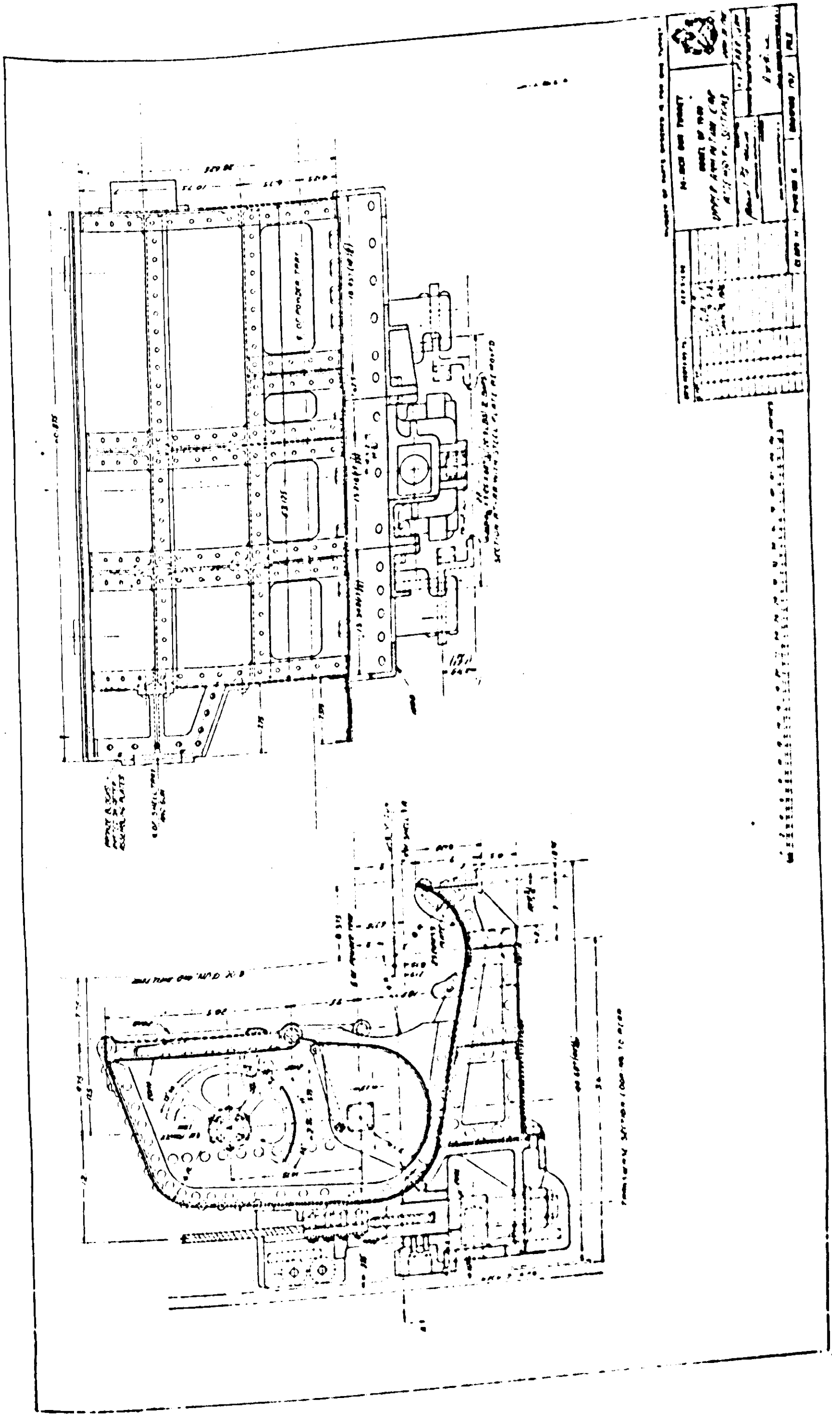

14-INCH GUN TURRET
MODEL OF 1919
LOWER AMMUNITION CAR
ASSEMBLY-SECTIONS
SECTION — A-A
SECTION — B-B
SECTION — C-C
SECTION — F-F
SECTION — G-G
FOR FULL VIEWS SEE-179 F

PLATE 194.



nected by fixed frogs to a circular track located over the loading table, Plate 192. The projectiles are dropped by the trolley hoists onto the loading table, from which they are transferred to the lower ammunition car. The powder is carried from the magazine and placed in the lower ammunition car by hand. The lower ammunition car, Plate 193, is hoisted by means of a rope and drum to the level of the upper handling room, where the projectile and powder are automatically dropped out on receiving trays, from which they are transferred to the upper ammunition car, Plate 194, in which the powder and projectile are hoisted to a position convenient for loading opposite the breech of the gun. The upper and lower ammunition cars are operated by ropes and drum driven by motors. In case of derangement of the electrical apparatus, the auxiliary shell hoist is provided. This auxiliary projectile hoist consists of vertical trunks extending from the lower handling room to the gun chamber of the turret. One hoist is provided for each gun and consists of two buckets hanging on opposite ends of a chain passing over pulleys and operated manually by a double nonoverhauling gear. When the projectile is delivered by the auxiliary hoist on the turret floor it is picked up by a small trolley hoist and is carried to a position opposite the bore of the gun. In case of derangement of the ammunition hoist, the powder must be hoisted by block and tackle from the lower handling room to the guns. The details of this ammunition supply system are so elaborate and so many that it does not seem wise to devote space here to a complete description, for it will be understood that this ammunition supply system is complicated by the fact that the ammunition is stored in concrete underground shelters and is supplied to the gun chamber through hoists of a type similar, to a degree, to those provided on the average battleship. Various types of emergency equipment are of course provided in the event that the equipment in general use should be deranged. The reader who is interested in a more elaborate description of the various details is referred to the complete description given on pages 64 to 75 of Pamphlet No. 2001, "Instructions for Mounting, Using, and Caring for 14-inch Gun Turrets, Model of 1909."

7. 14-INCH 40-CALIBER GUN, MODEL OF 1919, ON RAILWAY MOUNT, MODEL E.

397. The design of this mount, Plates 195-208, was practically finished at the time of our entry into the World War. It was designed primarily for service in the coast defenses, although a number of special provisions which adapt it especially for coast defense adapt it likewise for certain types of field service. It can be operated either as a sliding or as a fixed emplacement mount. Only one mount of this design has been finished, but it has made so

favorable an impression from its performance in recent tests against a moving target at a distance of 6,000 yards, when the difficulties of following a rapidly moving target are extreme, that it is probable that a new mount embodying most of its desirable features, as well as other features found imperative for field service, will be made up shortly.

398. *Cannon.*—See E, paragraph 354. The cannon is not provided with a trunnion band in this case, but it fitted with a spline or key which slides in a splineway in the cradle.

399. *Breech mechanism and firing mechanism.*—See B, paragraphs 279 and 287.

400. *Recoil mechanism.*—This recoil mechanism, Plate 195, comprises a single recoil cylinder attached to the cradle in the center at the bottom, the piston rod of which is attached to the relatively light recoil band of the gun. With the exception of the provision of a counter-recoil buffer, this cylinder is similar to the short cylinder described under A, paragraph 258. The extension of the piston rod in this case serves as a counter-recoil buffer. The space normally occupied by the buffer fills with oil when the gun recoils. When the gun returns to battery the oil in this space can pass to the rear only slowly through the clearance about the buffer. The maximum length of recoil is 60 inches.

401. *Recuperator mechanism D.*—The recuperator, Plate 195, comprises six spring cylinders attached to the cradle—four above and two below. Each spring cylinder comprises three columns of springs divided into seven sections. The spring rods are attached to the recoil band of the gun. This is the type of recuperator common on barbette and field carriages before the introduction of the pneumatic recuperator. All except one of the carriages installed by the Germans on the Belgian coast employed recuperators somewhat of this type. Most British and many French heavy carriages likewise employed this type throughout the war. Sometimes the spring wire is circular in section, sometimes oval, and sometimes rectangular. Their most serious defect is their lack of strength. It would be practically impossible to make springs of proper capacity to use them in connection with a 16-inch 50-caliber gun without having their weight prohibitively excessive.

402. *Elevating mechanism.*—Provision is made for elevating the gun from its loading angle, 0 degree, to a maximum elevation of 30 degrees. The details of the elevating mechanism are shown on Plate 196. This elevating mechanism is essentially the same in design as that provided on the 14-inch Navy mounts, Marks I and II. It will be observed on the above-noted plate that the mechanism is made up of one large screw hinged to the bottom of the cradle by means of a yoke and trunnions and passing through a large nut in the oscillat-

PLATE 195.

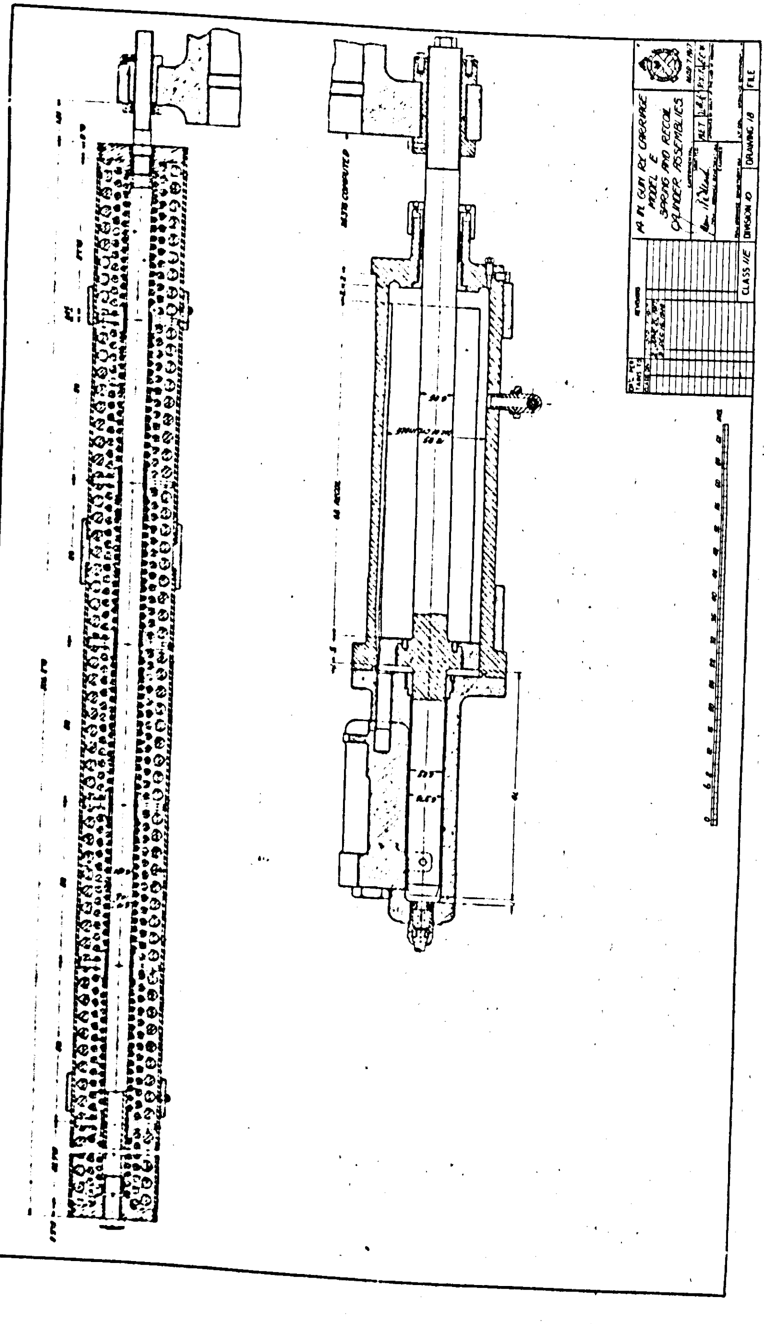
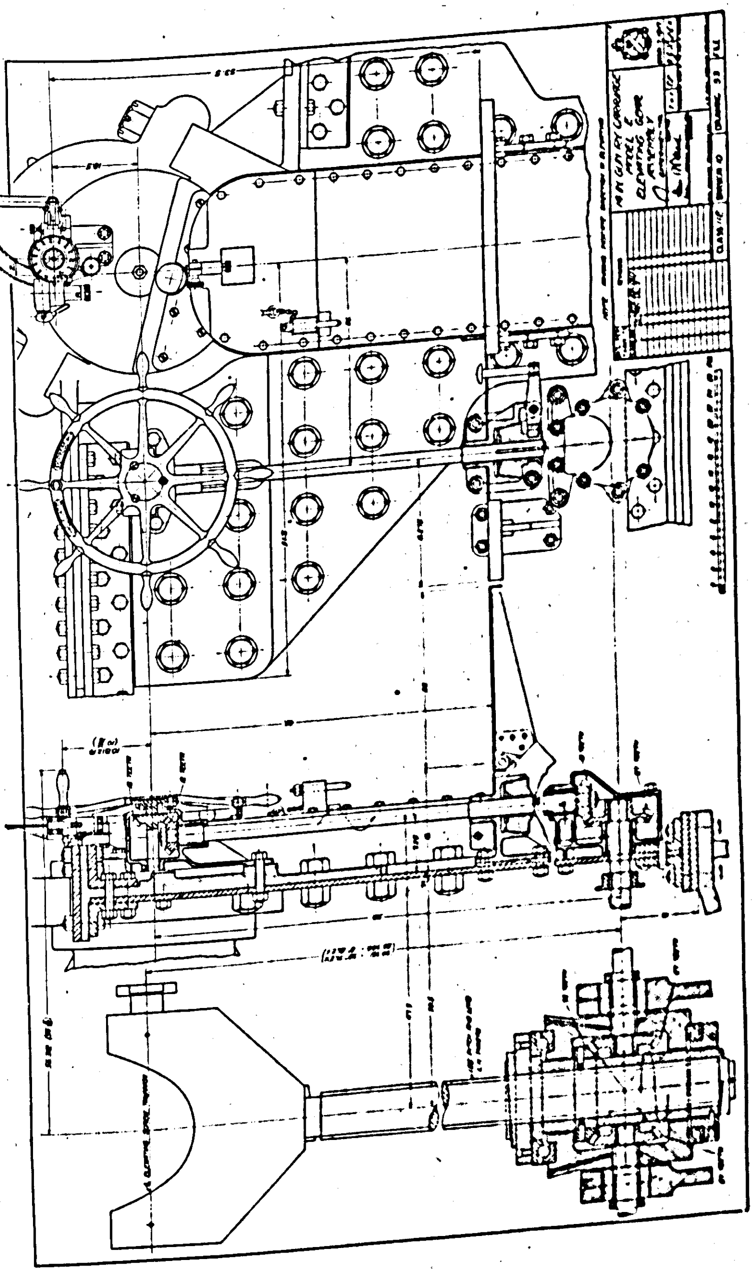

14 IN. GUN RY CARRIAGE
MODEL E
SPRING AND RECOIL
CYLINDER ASSEMBLIES
CLASS IIE
DIVISION IO
DRAWING 18
FILE

PLATE 196.



ing housing, which is in turn supported by its trunnions in bearings attached to the car body. This nut is provided with a ball-thrust bearing, as shown on Plate 190, and is driven by miter gears, which communicate with the handwheel through the horizontal cross shaft and two more sets of miter gears. The elevating handwheel is mounted on the right side of the carriage just behind the trunnion. Each trunnion is equipped with an antifriction device of the design shown on Plate 197. This is of the rolling-wedge or knife-edge type, and again is almost identical in design with the antifriction device provided on the Navy 14-inch mounts. It is composed of a fulcrum arm whose rounded lower end rests in a bearing block, which in turn rests on the adjusting wedge. The upper end of the fulcrum arm is rounded to a radius equal to the distance from the center of the lower end to the center of the top, and bears directly against the underside of an extension of the main trunnion. Both the fulcrum arm and the trunnion are fitted with gear-toothed segments, which mesh with each other and prevent slipping of the arm. The device is adjusted by means of the wedge under the bearing block at the bottom of the gun. When properly adjusted this device carries the weight of the gun while it is being elevated and depressed, thereby reducing considerably the effort required. When the gun is fired the force of recoil is transmitted, even at the maximum firing angle of 30 degrees, almost entirely into the main trunnion bearing. This mechanism is inferior to the type used in the service of the other mounts already described in that it contains no flexible parts that can bend or be compressed under the force of recoil and permit that force to be communicated more easily and directly to the main trunnion bearings. One turn of the slow-operating handwheel elevates the gun through 0.33 degrees, and one turn of the fast-operating crank elevates the gun through 1.1 degrees.

403. *Traversing mechanism.*—This mount can be traversed through 360 degrees by means of a mechanism the design and details of which are shown on Plates 198 and 199. The entire mount rests by means of four conical rollers on a cast-steel base plate. To the center of the base plate is bolted a pintle which takes the horizontal component of the force of the recoil; gears are cut on the inside of the roller path to serve as a traverse rack. The traverse pinion is cut in the bottom end of a vertical shaft which can be raised for traveling or lowered to mesh with the traversing rack for traversing the mount. This shaft passes through and is driven by the large horizontal bevel gear, as shown on Plate 199, which is in turn driven through the gears by two hand cranks on the sides of the carriage. The gear case through which the horizontal driving shaft passes on the left side of the carriage, Plate 199, contains a large bevel gear, loose on the shaft, but which may be thrown into gear with the shaft

PLATE 197.

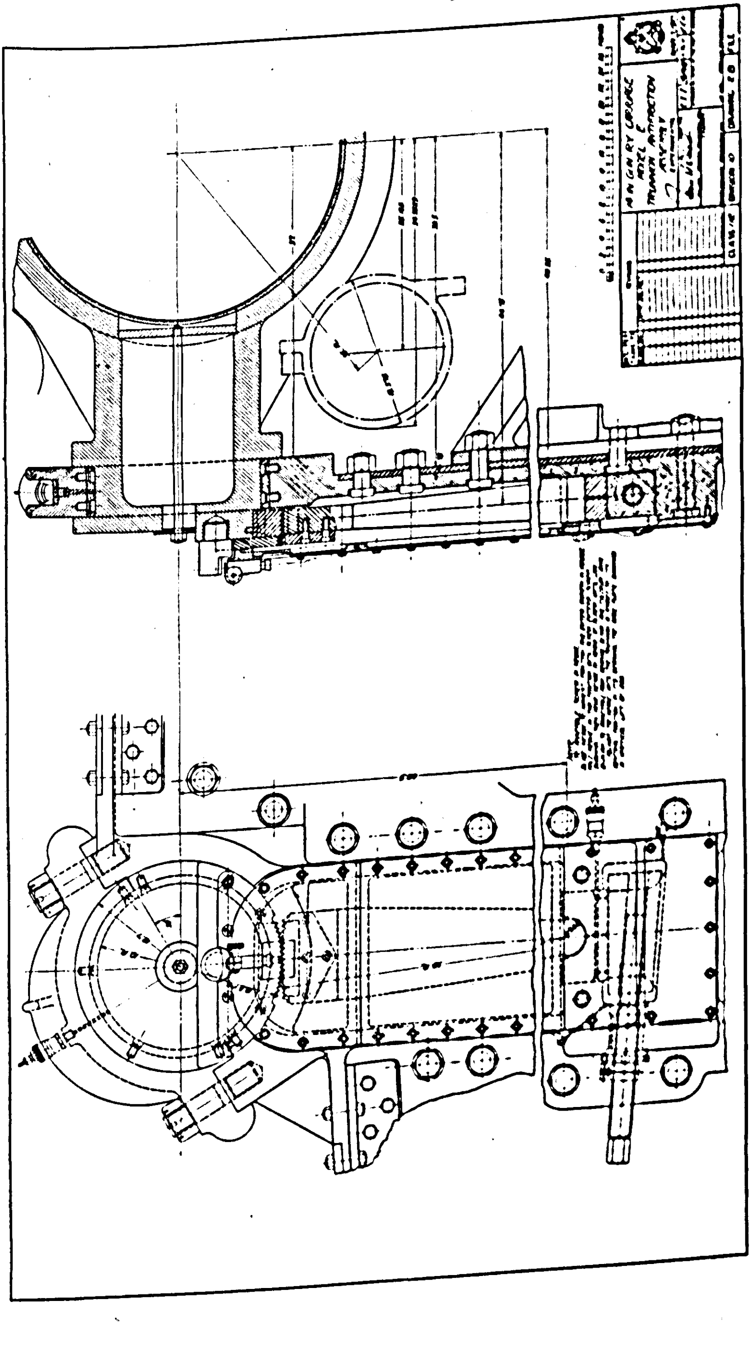
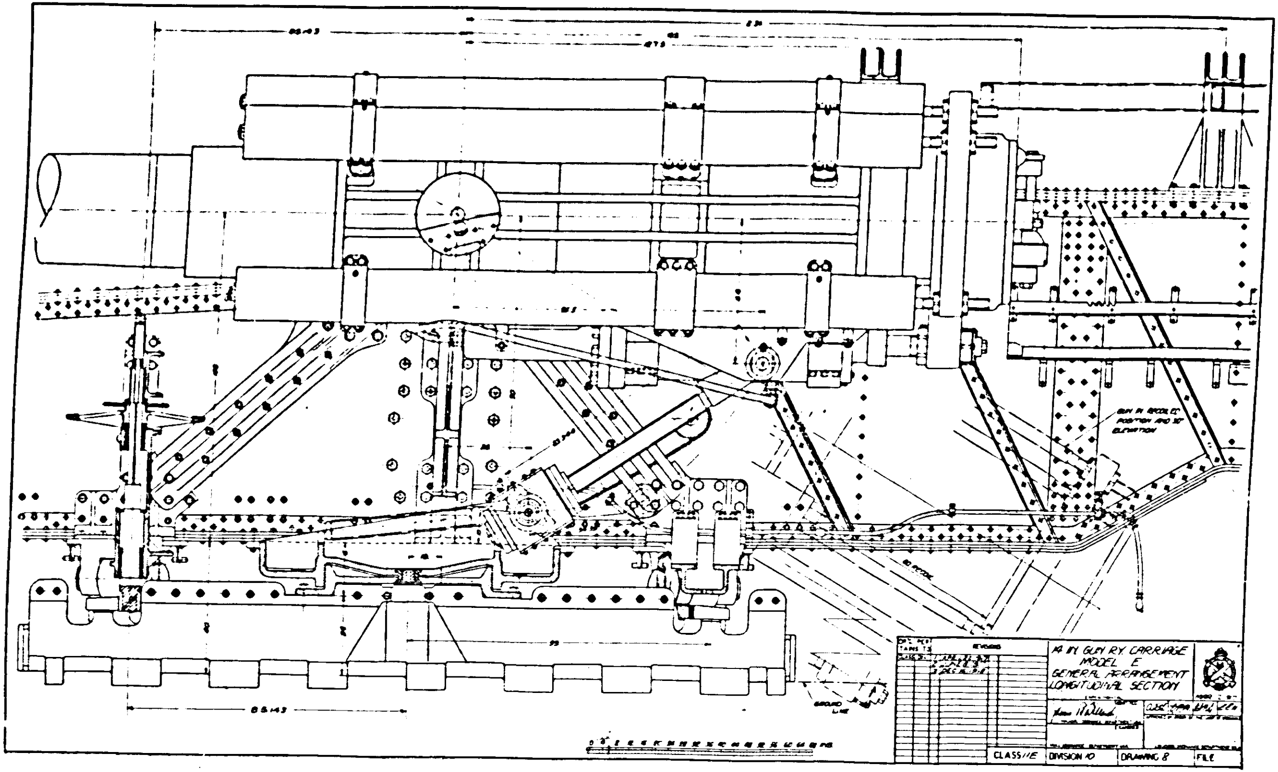
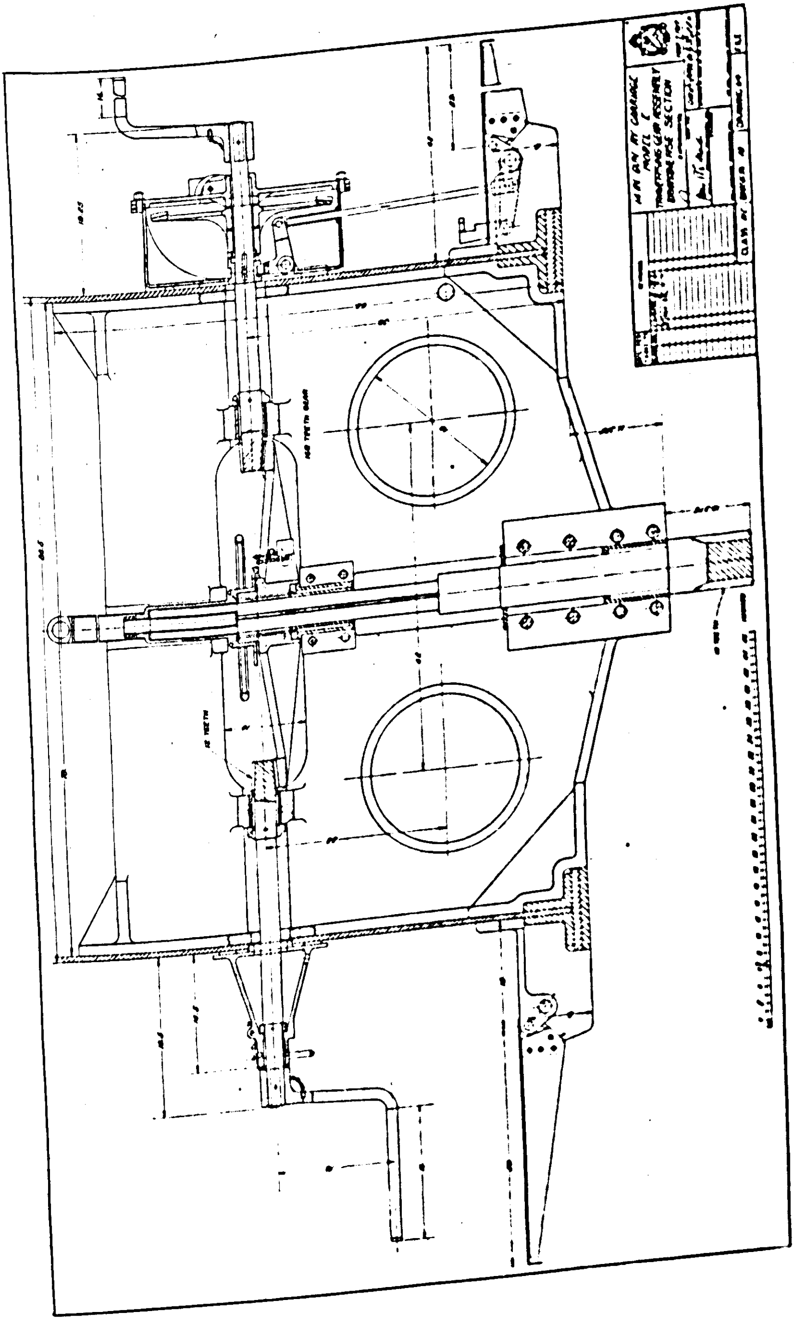


PLATE 198.



MOUNT LOWERED ON BASE.

PLATE 199.



by a foot-pedal operated clutch. When the clutch engages the gear, the traversing mechanism is operated by the handwheel somewhat to the rear of the crank. This handwheel is for slower motion and is used for the final fine adjustment.

404. It has been noted before that the gun can be fired without the use of a firing platform to an elevation of 22 degrees. To secure any great amount of traverse under this elevation, it is of course necessary to operate the mount on a curved track. For fine adjustment, a car-body traversing mechanism of the design shown on Plates 200 and 201, is used. It will be observed here that cast-steel body bolsters, riveted into each end of the car, carry a traversing beam which is fixed with respect to the truck when the lifting bolster is down. Between this traversing beam and the body bolster are two rollers, 5.33 inches in diameter and 23 inches in length, on each end of which are cut spur gears which mesh with racks attached to the body bolster and the traversing beam. The traversing beam is connected with the handwheel on the left side of the carriage, Plate 200, by means of a screw and spur gears. The mount is capable of being traversed 0.25 degrees on each side of the center, at each end of the car, by means of this mechanism, thereby securing a total traverse of 1 degree. One turn of the handwheel moves one end of the car through 0.093 degrees. As the handwheel is turned, the traversing screw moves either in or out of the traversing beam. As noted before, the traversing beam is fixed with respect to the trucks, and the car body must therefore move on the traversing rollers.

405. *Loading mechanism C.*—The design of the loading gear is shown on Plates 202, 203, and 204. It will be seen on the first plate that the projectiles can be picked up from the ground or from a platform at the rear of the carriage by means of chain hoist carried on an I-beam trolley. The projectile is carried forward and placed on the shot truck, the wheels of which ride on angle-iron rails. The shot truck is run forward with as great a velocity as possible until its buffer strikes the breech of the gun, when the projectile slides on into the powder chamber. The projectile is then rammed by hand. The powder charge is picked up from the rear and placed on the shot truck by means of the same hoist, the truck runs forward and the powder rammed the same as the projectile.

406. When it is desired to fire at angles above 22 degrees, beyond which the breech of the gun on full recoil would strike the railway ties, it is necessary to place the mount on the cast-steel base ring, the design of one-half of which is shown on Plate 205. This base ring may be laid either on a concrete subbase or on rock ballast. When placed on rock ballast it is necessary to brace it against lateral movement by means of 64 steel piles 4 feet long driven around its cir-

PLATE 200.

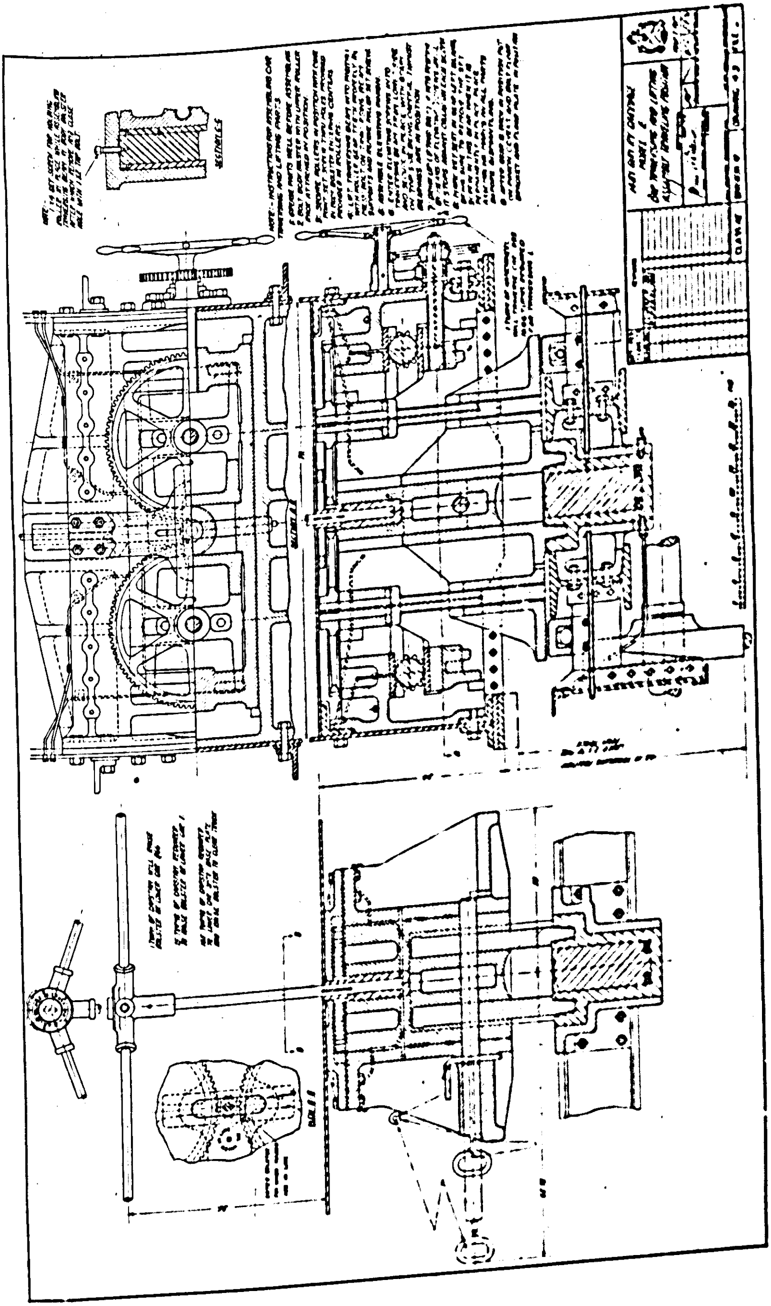


PLATE 201.

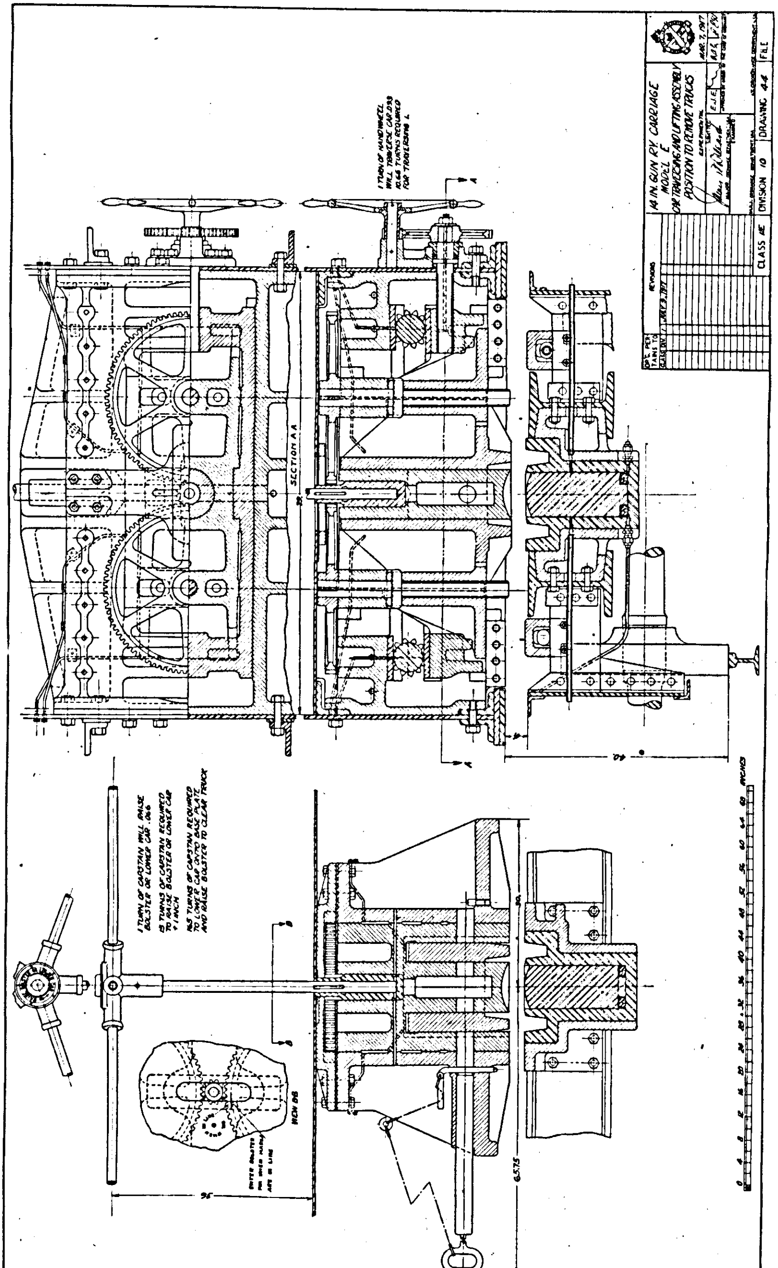
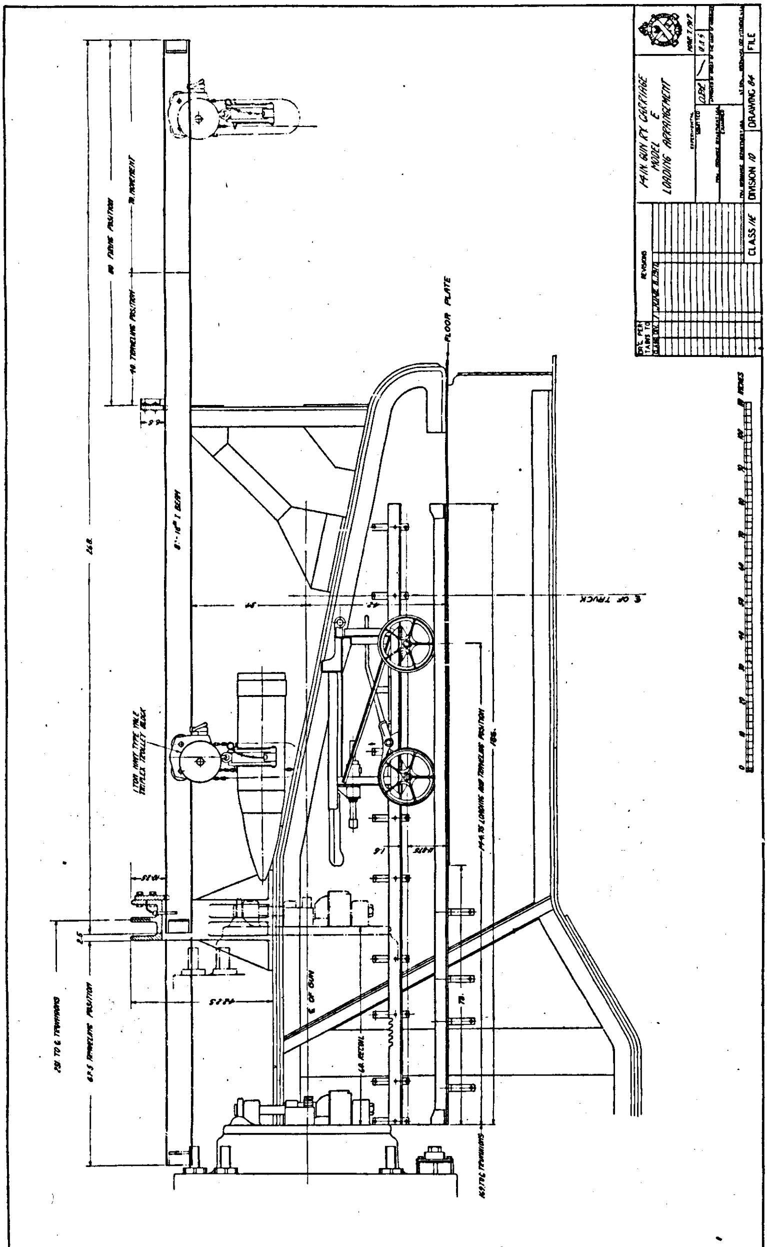
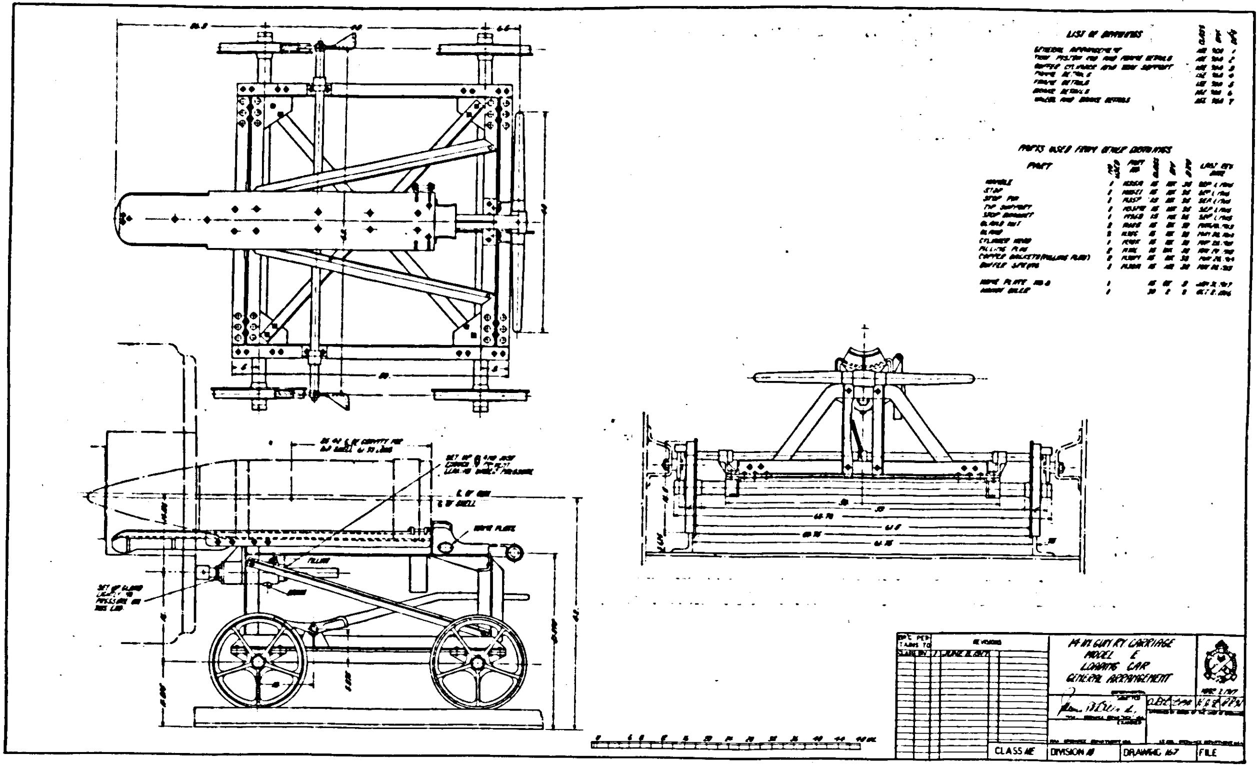

14 IN. GUN RY. CARRIAGE
MODEL E
CAR TRAVERSING AND LIFTING ASSEMBLY
POSITION TO REMOVE TRUCKS
MAR. 7, 1917
REVISIONS
CLASS AE
DIVISION 10
DRAWING 44
FILE
1 TURN OF HANDWHEEL
WILL TRAVERSE CAR .093
FOR TRAVERSING
1 TURN OF CAPSTAN WILL RAISE
BOLSTER OR LOWER CAR .066
15 TURNS OF CAPSTAN REQUIRED
TO RAISE BOLSTER OR LOWER CAR
1 INCH
TO LOWER CAR ONTO BASE PLATE
AND RAISE BOLSTER TO CLEAR TRUCK
SECTION A A
INCHES

PLATE 202.

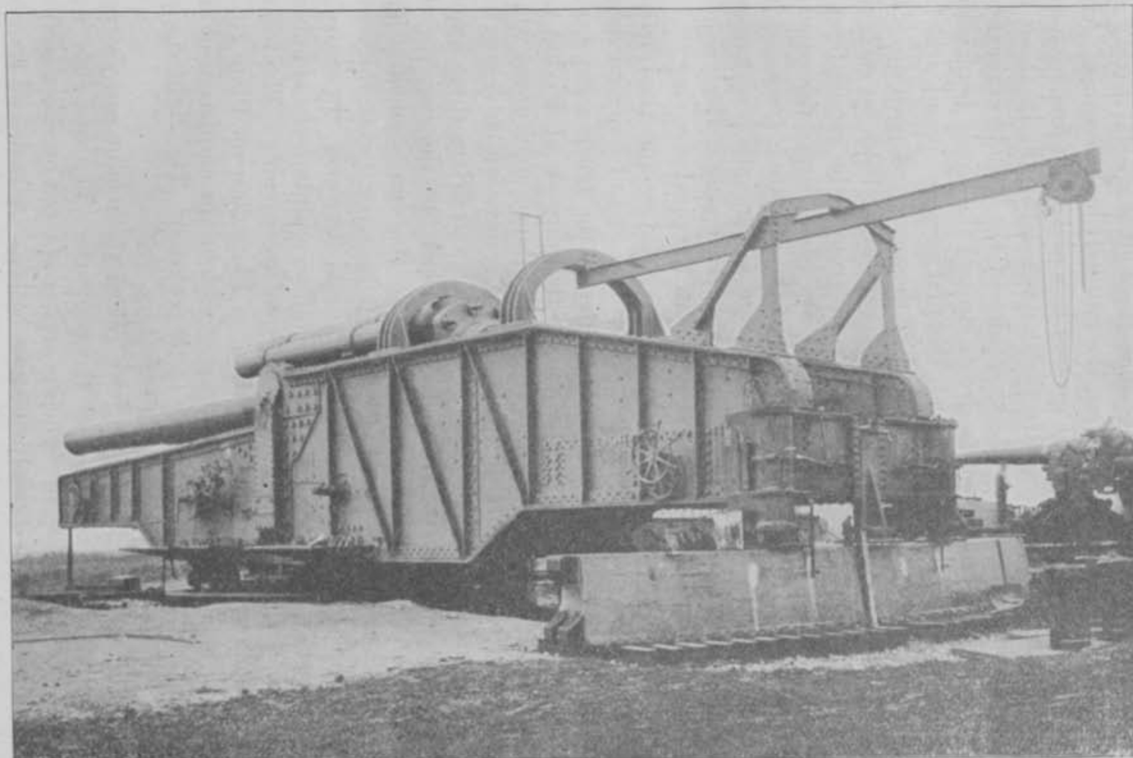


ELEVATION OF LOADING BIG SHOWING OVERHEAD TROLLEY AND SHUTTLE CAR.

PLATE 203.



SHUTTLE CAR FOR CONVEYING PROJECTILE FROM OVERHEAD TROLLEY TO BREECH OF GUN.



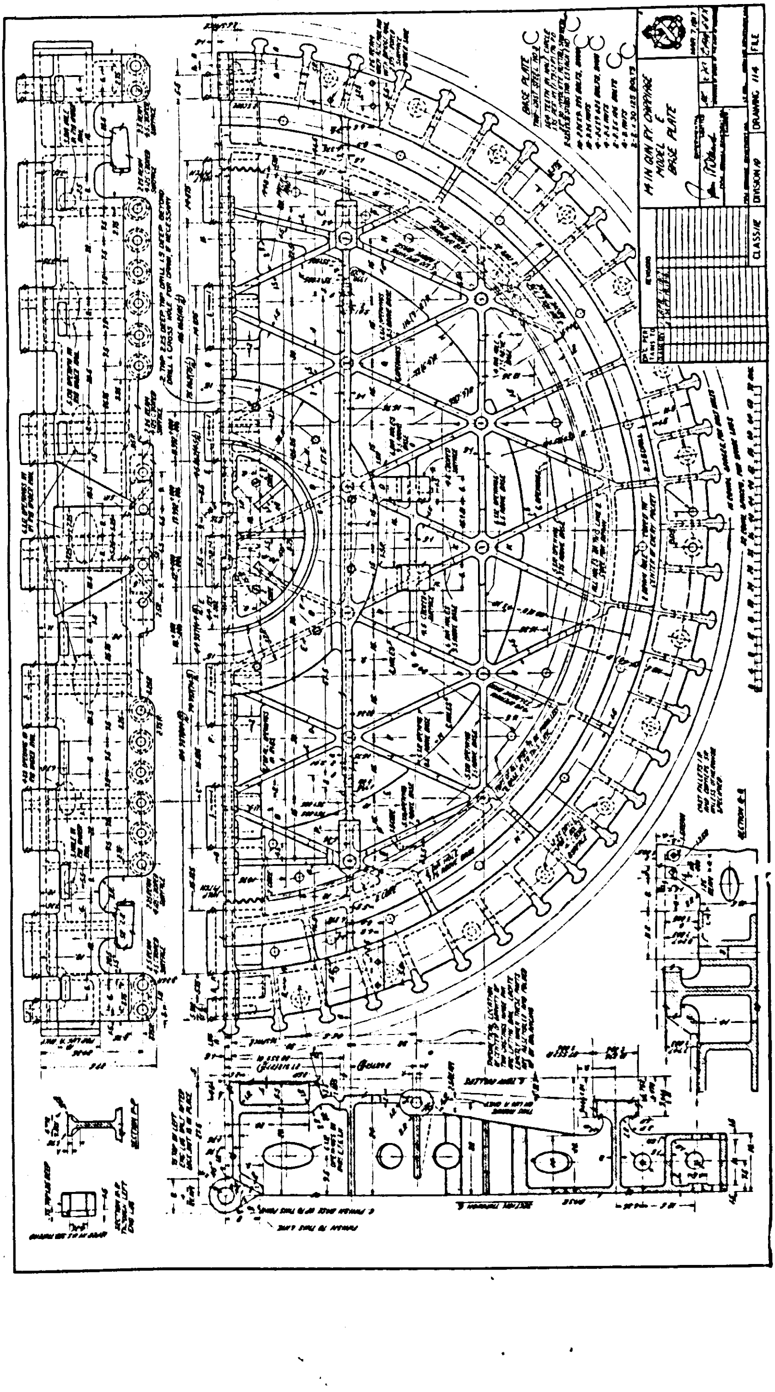
14-INCH GUN RAILWAY CARRIAGE MODEL E IN FIRING POSITION.

cumference. The base ring is in halves and in traveling is carried folded on a standard flat car. The full capacity of a 160-ton locomotive crane is required to handle the base in process of installation. It is first removed from the car and placed on the ground beside the emplacement, the lifting being done through a special lifting eye attached to the hinge pin between the two half-base sections. After the base has been placed on the ground it is picked up first by means of this lifting eye. Chains are then attached to pins in about the center of each half and to the two sides of the double crane hook. After the double crane hook is drawn up and the single hook which is attached to the eye is lowered, the platform is spread and laid in place on the level ballast surface of the prepared position. The two segments are then bolted together with eight bolts on each side of the center and the steel piles driven around the circumference, Plate 206. Four special rail sections are placed over the concrete roller path and are bolted to the rails of the approach track. After these rail sections are installed the mount is run into position over the emplacement and lowered until the traversing rollers rest on the roller path and the pintle engages with the pintle bearing.

407. The mount is lowered by means of two identical lifting devices installed on the front and rear trucks and of a design shown on Plates 200 and 201. Above the center of the truck a capstan is mounted on the shaft of the pinion for the purpose of driving this lifting gear. This pinion meshes with two large spur gears which are attached to the ends of two identical screws which screw into the lifting bolster. As the capstan is turned and drives these screws, the bolster is raised or lowered with respect to the car, thereby lowering the car onto or raising it from the emplacement. This device is supplemented by a hydraulic lift incorporated in the center plate of the truck. When this lift is used, however, the movable bolster must be raised or lowered by hand to maintain the side bearing clearance and prevent the mount from overturning. The lifting bolster is shown in traveling position on Plate 200; on Plate 201 it is shown as located when the mount is resting on the emplacement and the trucks are removed or ready to be removed. The eight conical traversing rollers are removed in traveling.

408. When the lifting bolsters are raised the mount can be traversed until the rear end is over the supports. The cast-steel support beams are made up in segments and are placed on short sections of I-beams which rest directly on stone ballast. A cast-steel transom carrying two hydraulic jacks and one screw jack is riveted to the rear of the car body. These hydraulic jacks have swinging shoes which rest on the support beams and serve to prevent the mount from turning over in firing. Tests have been made which prove that the mount

PLATE 205.

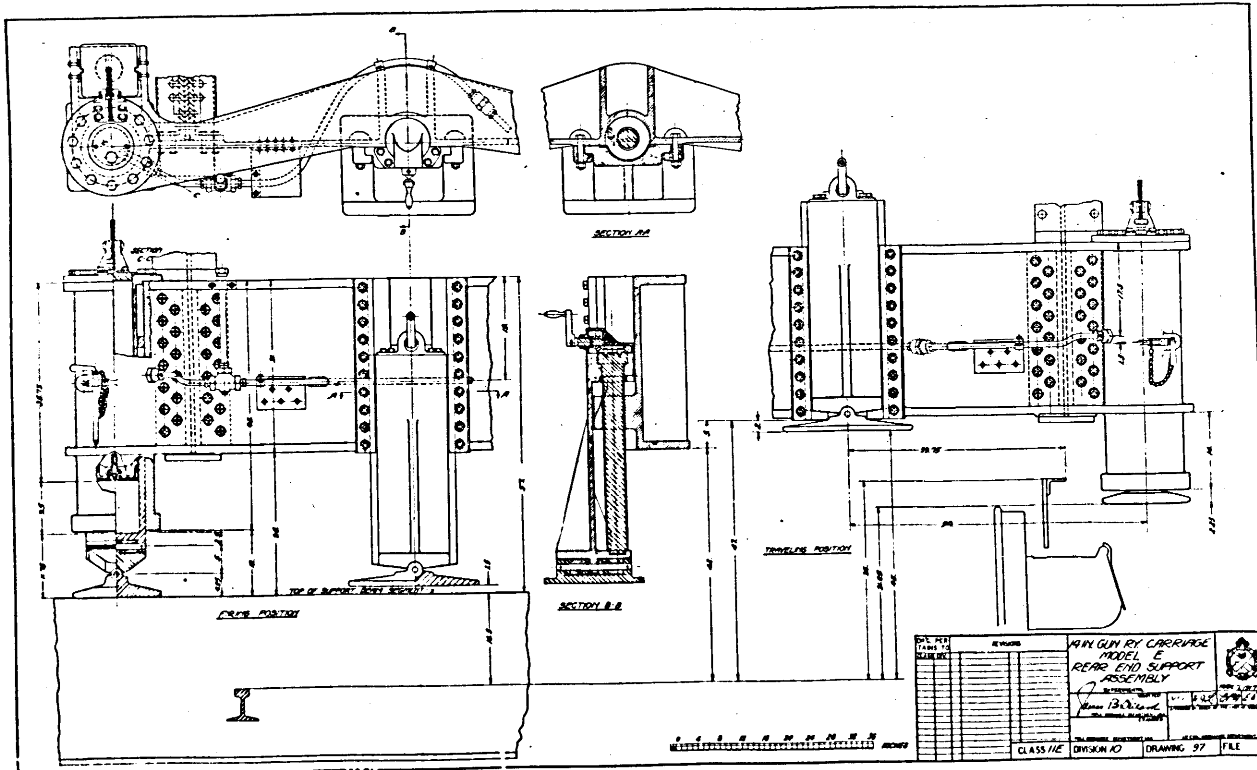


ONE-HALF SECTION OR THE 14-INCH MODEL E BASE.

PLATE 206.

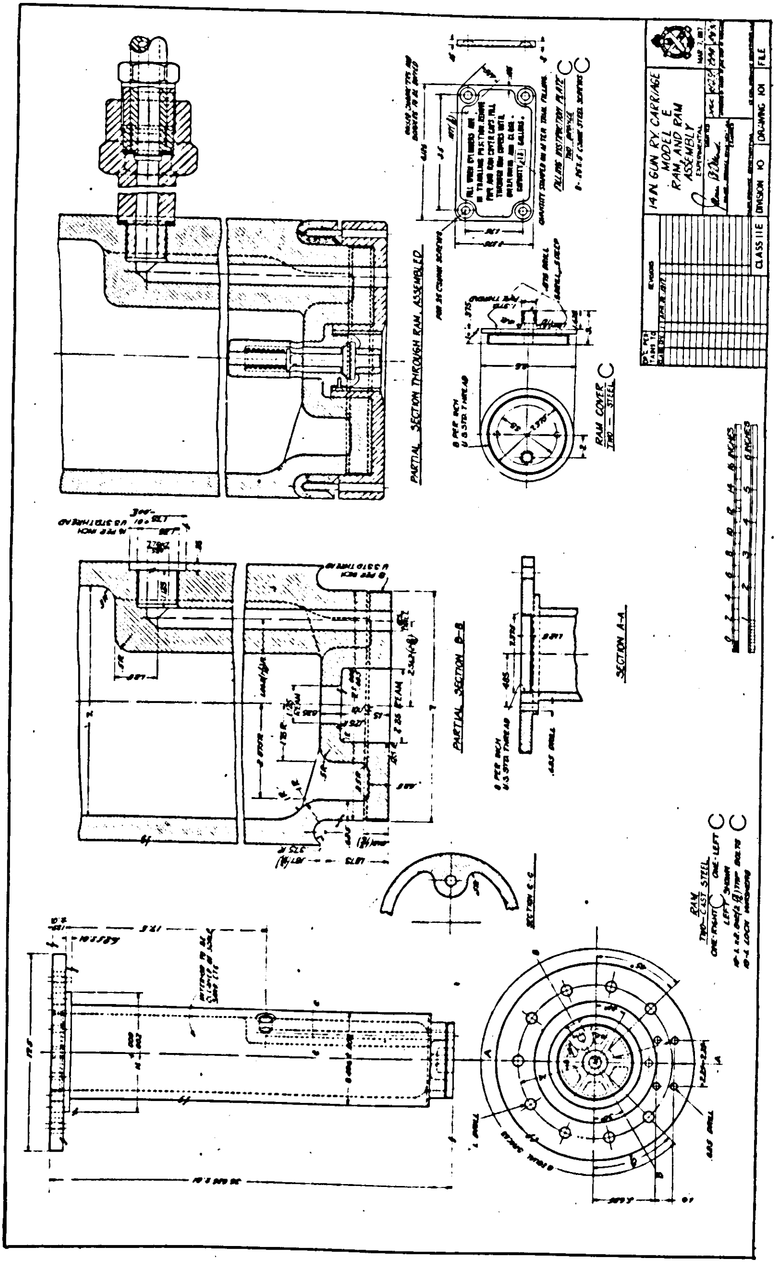
BASE PLATE AND TRACK INSTALLED FOR THE 14-INCH MODEL E RAILWAY MOUNT.

PLATE 207.



HYDRAULIC SUPPORT CYLINDER AND YOKE FOR THE MODEL E MOUNT.

PLATE 208.



HYDRAULIC RAM FOR REAR END SUPPORT.

can be operated without supports of this kind when the base ring is bolted to a concrete sub-base. The design of the hydraulic support cylinder is shown on Plates 207 and 208. No special mechanism is provided for raising or lowering the hydraulic cylinders. They can easily be raised or lowered by any sort of lever, such as a crowbar, and more easily when moved very slowly. In preparing for action the supporting beans are leveled very carefully and the hydraulic jack shoes are lowered until they bear on the greased top surface of the supports. A small cable is attached to the top of the movable cylinder and passes over the top of the pulley to the counterweight which balances its weight. The cylinder will remain in any position. As the cylinder moves up or down, the oil between it and the ram must pass through the valve shown in the center of the bottom of the ram, Plate 208. Any attempt to move the cylinder rapidly, as in the case when the gun is fired, simply serves to close this valve and prevent the cylinder from moving. Thus the cylinder can be brought down until its bearing plate rests on the support segments, and inasmuch as it exerts no pressure, no difficulty is caused in traversing; but the cylinder furnishes a positive support in firing, since, as noted above, any attempt to move it rapidly closes the valve in the ram. The top surface of the support beams is kept well greased.

8. 14-INCH 50-CALIBER GUN, MODEL OF 1920, ON RAILWAY CARRIAGE, MODEL OF 1920.

409. This railway mount, Plates 209–213, like certain other mounts that have been or will be described, is likewise a product of the World War. The 12-inch and 14-inch guns which the British Army mounted on railway carriages with provision for elevation as great as 45 degrees, the 340-millimeter guns mounted by the French on railway carriages, and the 14-inch guns mounted by our own Navy on railway carriages constructed by the Baldwin Locomotive Co. and used effectively from late August to November 11, 1918, in cutting the lines of communication between Sedan and Metz, showed very conclusively that such guns can be mounted on railway carriages and served very effectively against relatively small targets at long ranges. This mount combines the best features of all of the railway carriages that were constructed either by our Allies or our enemies. The scheme employed in placing the mount has been taken from the German 170, 240, and 280 millimeter railway mounts.

410. *Cannon.*—See A, paragraph 252. This 14-inch cannon is of the wire-wound type, and the principles of construction are the same as those described under A. Further information with reference to it may be found in the table of information.

411. *Breech, firing and recoil mechanism.*—See A, paragraphs 253, 257, and 258, respectively.

412. *Recuperator mechanism.*—See A, paragraph 261. The location of these cylinders on the cradle is shown on Plate 209.

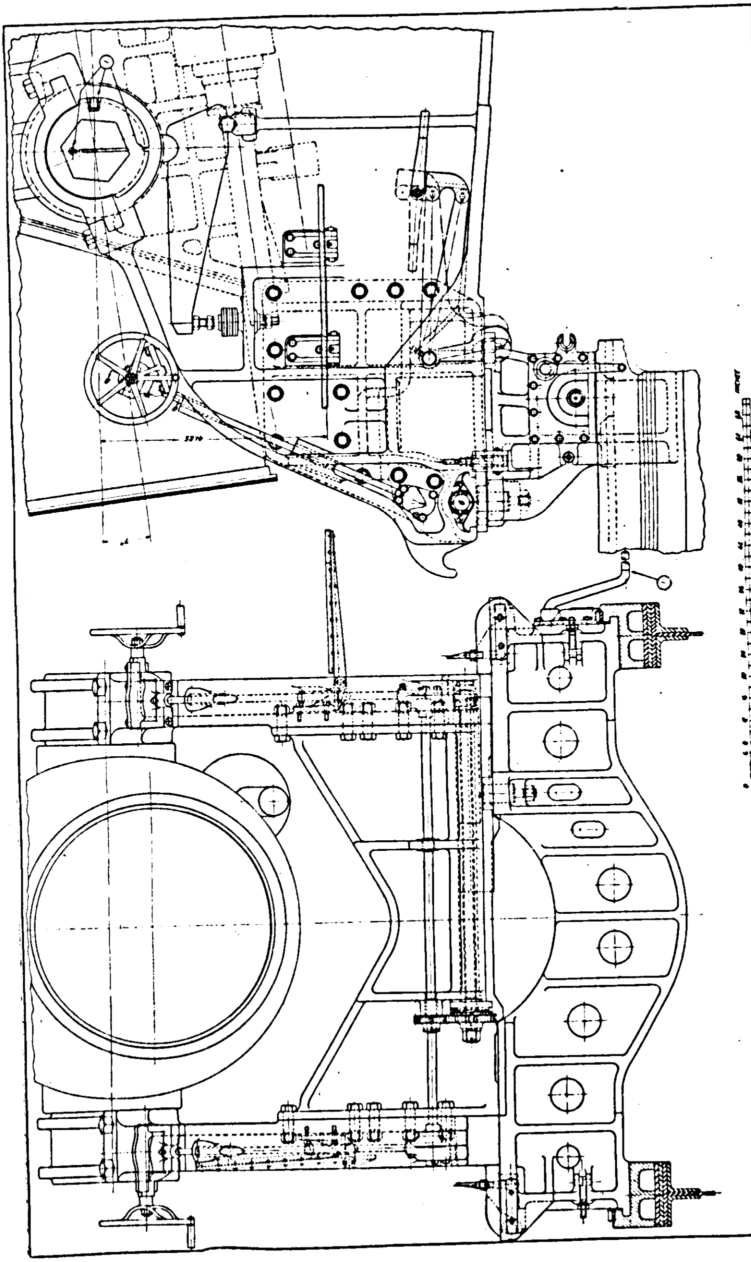
413. *Elevating mechanism.*—See A, paragraph 263. In principle the two are practically alike. It is possible to elevate this gun both by power and by hand. The details of the mechanism are shown on Plate 210.

414. *Traversing mechanism.*—The traversing mechanism, which was mentioned briefly in the introductory paragraph, comprises a pedestal mounted in a yoke swung between the side girders of the car body forward of the center and two traversing rollers attached to the car body somewhat to the rear. These rollers are driven through a traversing mechanism comprising spur gears leading to the traversing motor or to the hand cranks. The details of this mechanism are shown on Plate 211. It will be observed that 4-inch steel balls are used in the bearing of the pedestal. This is the first use in American heavy seacoast or railway carriages of balls in this type of bearing. It is possible to traverse the carriage through 360 degrees through the use of this mechanism.

415. *Loading mechanism D.*—This mount is provided with the gravity type of loading mechanism, the gun being depressed to an angle of 7 degrees. The mechanism comprises two power cranes, by means of which the projectile and powder units are lifted from ammunition cars, operating on a circular standard-gauge track surrounding the mount, and deposited on an inclined loading tray to the rear of the gun breech. A spanning tray somewhat longer than the recoil of the gun is extended forward from the loading tray into the screw-box of the breech. A slight impetus will start the projectile down the tray and, with its momentum increased due to gravity, embeds the rotation band so firmly in the origin of the rifling grooves that the gun may be safely elevated to the maximum without danger of the shell slipping backward. A short hand rammer is used to facilitate the more sluggish movement of powder bags down the trays. In traveling, the jib cranes and loading tray structure are folded down out of the way.

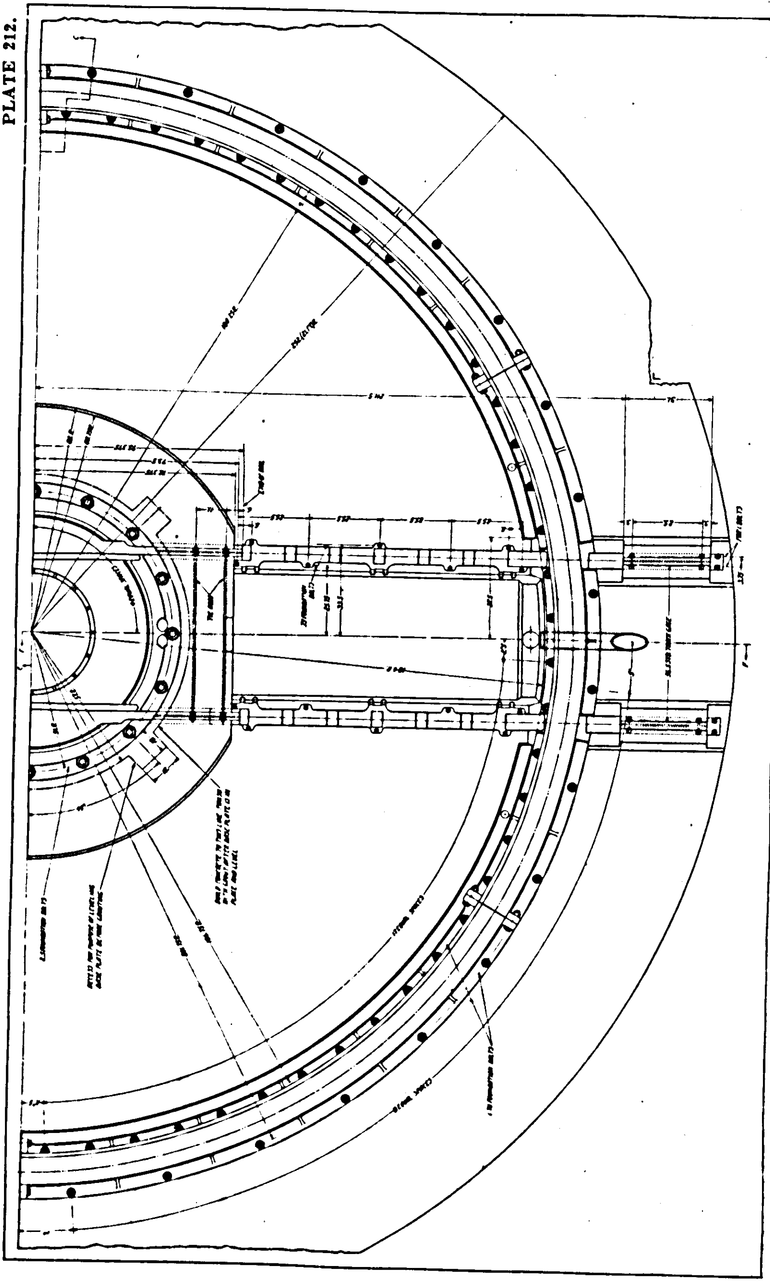
416. *Carriages.*—The mount comprises a top carriage unit and a specially designed railway car. The first consists of the cradle parts, and cast side frames with front and rear transoms and the whole unit capable of being traversed 3.5 degrees either side of central. This traversing mechanism for the top carriage is not utilized, however, when the mount is on its emplacement, but is intended for correction of azimuth when firing from a curved track with outriggers in place. As a permanent mount the top carriage is locked in the central position and the mechanism described in paragraph 414 is used for traversing. The lower carriage or railway car is composed of special alloy steel flanged girders with suitable transoms and con-

PLATE 211.



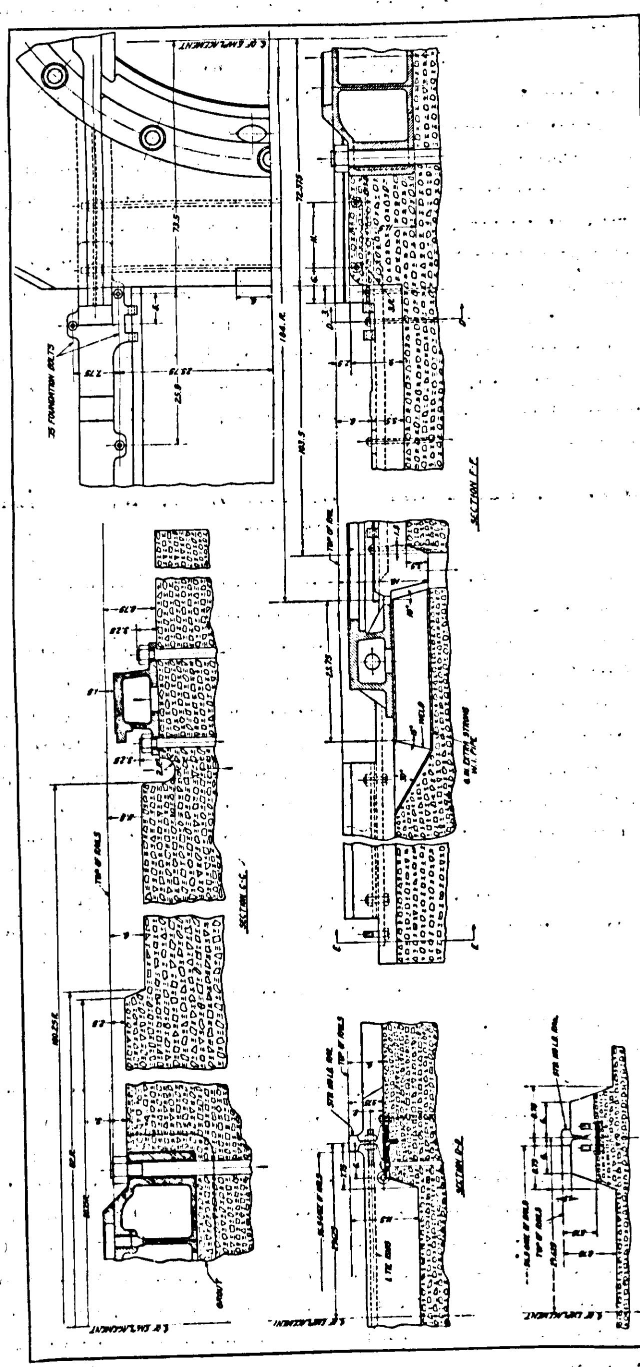
TOP CARRIAGE TRAVERSING MECHANISM.

PLATE 212.



PLAN VIEW OF EMPLACEMENT OF 14-INCH RAILWAY MOUNT, MODEL OF 1920.

PLATE 213.



SECTIONAL VIEWS OF EMPLACEMENT OF 14-INCH RAILWAY MOUNT, MODEL OF 1920.

tains the lower pintle or pedestal upon which the mount rests and the mount traversing unit.

417. *Base.*—Bolted to the large concrete block of the emplacement are the two main units of the base, Plates 212 and 213. The pedestal base upon which the main weight of the mount rests is in the exact center and bolted rigidly to the concrete foundation, and it is upon this cast steel base that the horizontal force of firing is expended. The base ring or roller path consists of six cast steel sections, bolted together and anchored to the foundation, forming a complete circle and containing a brass strip calibrated in degrees for azimuth settings. These emplacements, having no pit nor special drainage facilities, are relatively inexpensive and can be installed in numerous places of stragetic importance along the coast. Thus a relatively small number of these mounts can be utilized to cover a wide range of fortified area.

9. 12-INCH 10-CALIBER MORTAR OF 1908, ON MORTAR CARRIAGE, MODEL OF 1908.

418. *Cannon—F.*—This mortar, Plates 214–217, which is 10 calibers in length, weighs 8.125 tons, has a total length of 136.2 inches, a cylindrical powder chamber with a maximum diameter of 12.5 inches, and a length of 21.13 inches. It is rifled with 108 grooves twisting to the right at a uniform pitch of one turn in 20 calibers. The grooves are 0.2091 inch wide by 0.06 inch deep; the lands are 0.14 inch wide. The maximum powder charge is 58.25 pounds, the maximum powder pressure 37,000 pounds per square inch, and the muzzle velocity 1,500 feet per second with a projectile weighing 700 pounds. Both this mortar and the model of 1912 are wire wound, Plate 214, and comprise a tube, a wire envelope, jacket, trunnion hoop, and breech bushing. It is interesting to note this principle of construction in a mortar.

419. *Breech mechanism.*—See C, paragraph 343. The block is rotated 30 degrees to open or close it.

420. *Firing mechanism.*—See B, paragraph 287.

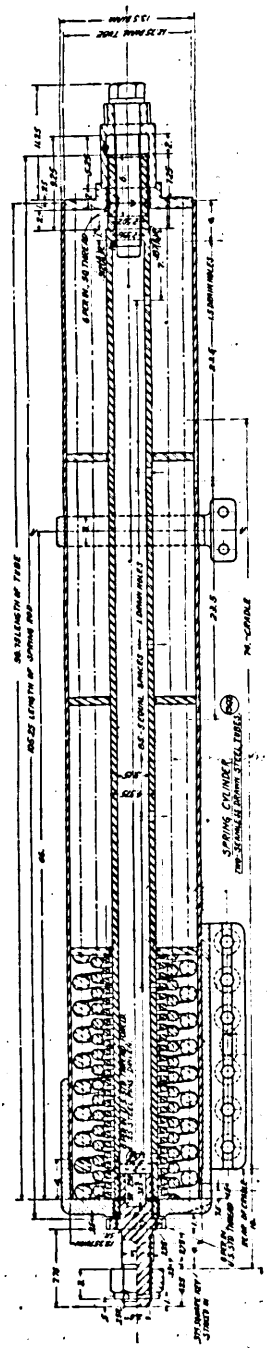
421. *Recoil mechanism.*—The recoil mechanism of this carriage comprises two hydraulic recoil cylinders contained on either side at the bottom of the cradle, Plate 215. They are shown in detail on Plate 216. It will be observed that this gun, because of its lack of length, is mounted in a sleigh, the runners of which slide in large grooves in the cradle. A hoop or band about the rear of the gun is attached to the two runners of the sleigh and the sleigh runners fit over the trunnions of the gun. The recoil piston rods are then attached to the recoil band. This band is not shrunk on, but simply fitted on and the sleigh runners bolted to it. When the gun

fices. In principle this is not unlike that of the other carriages already described.

422. *Recuperator mechanism.*—The recuperator mechanism of this carriage comprises two spring cylinders of the design shown on Plate 217 and mounted above and on either side of the carriage. Each recuperator is made up of three columns of springs divided into four sections. These springs have sufficient strength to retain the gun at its maximum elevation of 65 degrees and permit a recoil of 24 inches. These cylinders are attached to the top of the cradle and the spring rods are attached at the rear to the recoil band.

423. *Elevating mechanism D.*—The elevating mechanism comprises a single rack attached to the bottom of the cradle in the center, from which a train of spur and level gears leads to a slip-friction device and the elevating handwheel on the left side of the gun. There is considerable jump to this mortar, and it is necessary to have some slipping device incorporated in the elevating mechanism to prevent breaking of the gears. This jumping of the mortar on firing can not be considered a fault and has nothing to do with the accuracy of firing. The slip-friction device comprises a series of steel and bronze disks, some of which are attached to the worm wheel, which is driven by a handwheel through a worm. The alternate disks are keyed to the elevating pinion shaft. It is possible to vary the friction between these disks by drawing up on a clamping nut. When the gun jumps from firing, this slip-friction device permits

PLATE 217.



RECUPERATOR OF 12-INCH MORTAR CARRIAGE, MODEL OF 1908.

a slight motion in the elevating mechanism before the elastic limit in the metal of the various gears is reached. This is the first description of this type of mechanism that has been given and will be referred to on numerous occasions later. It should be observed here also that this carriage makes use of a worm and worm wheel in the elevating mechanism, a design that is considered undesirable at the present time and is not being used in recent mounts.

424. *Traversing mechanism.*—This traversing mechanism is not different in principle from A, paragraph 268, described for the 16-inch barbette carriage, nor the 16-inch disappearing carriage. It comprises a series of conical rollers carried in a distance ring, a conical roller path on the base and conical roller bearings on the racer, a rack made in sections and attached to the base ring and pinions, vertical shaft, worm wheel, and worm leading to the handwheel on the pedestal on the right side of the carriage.

425. *Loading mechanism.*—The loading mechanism of this mount comprises a shot truck operated by hand and carrying a single projectile, as under B, paragraph 326. The gun is loaded at zero degrees elevation and the shot truck brought so that its lip extends over thread in the breech bushing. The projectile is rammed by hand. The powder charge of 58 pounds is carried up by hand in a two-man tray and placed in the gun either from the shot truck or by hand.

426. *Top carriage D.*—The top carriage comprises two cast-steel side frames, Plate 215, with trunnion bearings machined to take the trunnions of the cradle. These side frames are bolted rigidly to the racer and are further braced by a transom forward of the trunnion support. The inner surface of the racer is machined to serve as part of the pintle mechanism, the bronze wearing ring being attached to the base ring. The working platform is attached to the outer edge of the racer and comprises a series of cast-steel brackets on which a sheet-metal floor is laid.

427. *Base.*—This base is made in two parts and comprises simply a cast-steel ring machined to serve as a conical bearing and to take the bronze pintle ring and the traversing rack. It rests on concrete in the emplacement, being bolted to the concrete by a series of anchor bolts.

10 AND 10A. 12-INCH MORTAR, MODELS OF 1890 AND 1912, ON MORTAR CARRIAGES, MODELS OF 1896 MI, MII, MIII.

428. *Cannon.*—The mortars of the model of 1890 are 10 calibers in length, of the built-up design, Plate 218, weigh 13 tons, have a total length of 141.12 inches, have a cylindrical powder chamber with a maximum diameter of 12.5 inches and length of 21.13 inches. They are rifled with 72 grooves twisting to the right at a varying pitch of from one turn in 40 calibers at the origin to one turn in 20 calibers at

gun recoils on firing, its trunnions are constrained to move in a circle about the axis of the yoke. This motion of the trunnion of the gun in a circle, of course, causes an oscillation of the recoil cylinders first for a short distance in one direction and then in the reverse direction. It will be observed on Plates 221 and 222 that the buffer is of still another form. In this case the top part of the piston is machined out to fit over an extension of the stuffing box. As the piston rod is forced down the oil passes above the piston and fills the recess. When the gun returns to battery the oil is pocketed in this recess and emerges only slowly, thereby preventing the gun from charging into battery.

434. *Recuperator mechanism E.*—The recuperator of these carriages comprises four sets of spring columns made up of two columns each divided into five sections. The collar over the upper end of the spring column bears against a machined surface of the spring yoke and the lower end of the top column bears against a collar on top of the adjusting nut. The bottom of the section of the spring column rests within a machined pocket in an oscillating spring support. The spring rod is free to move through the bottom of the oscillating spring support and through the top of the collar at the upper end of the column. The spring column is adjusted through the adjustment and locking nut shown at the lower end. These five spring columns have sufficient strength to maintain the gun in battery loaded. The angle of elevation has no effect to either decrease or increase the load on this recuperator.

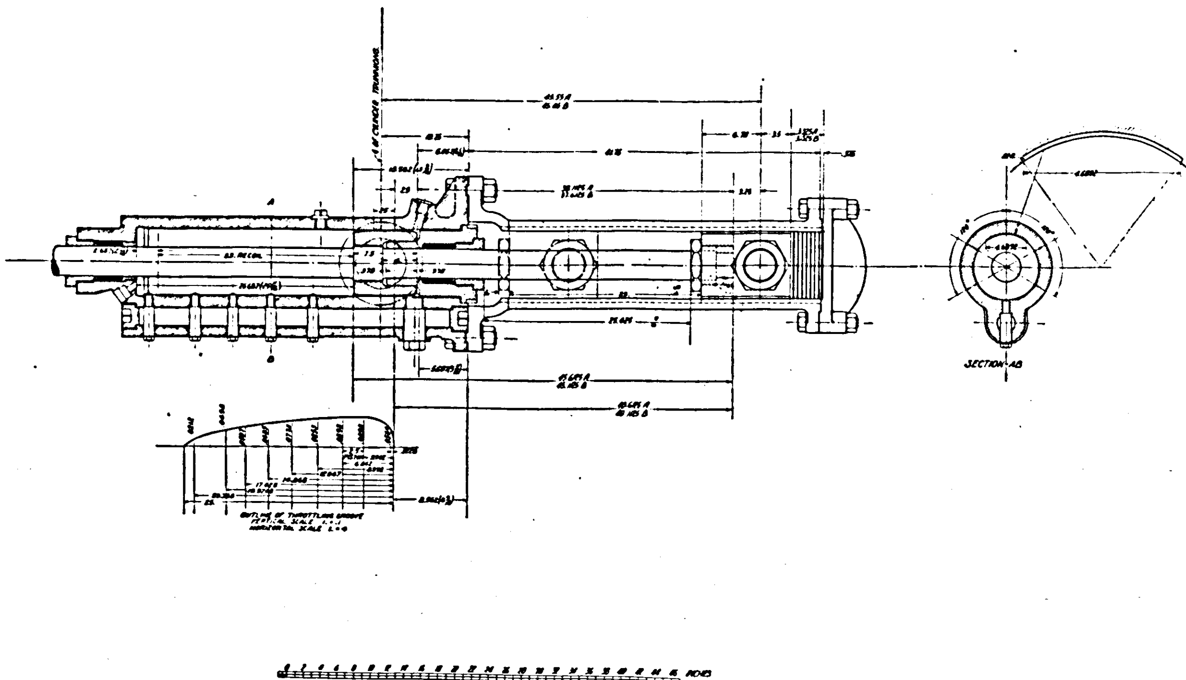
435. *Elevating mechanism.*—The elevating mechanism, Plate 223, comprises two handwheels mounted on a single shaft leading through a train of spur gears and a slip-friction device to an elevating shaft carrying a single pinion meshing with a circular elevating rack bolted to the bottom of the gun. The range of elevation is from zero to 70 degrees, and the ratio of the gearing is one turn of the handwheel per 2.36 degrees of elevation.

436. *Traversing mechanism.*—See paragraph 424.

437. *Loading mechanism.*—See B, paragraph 326.

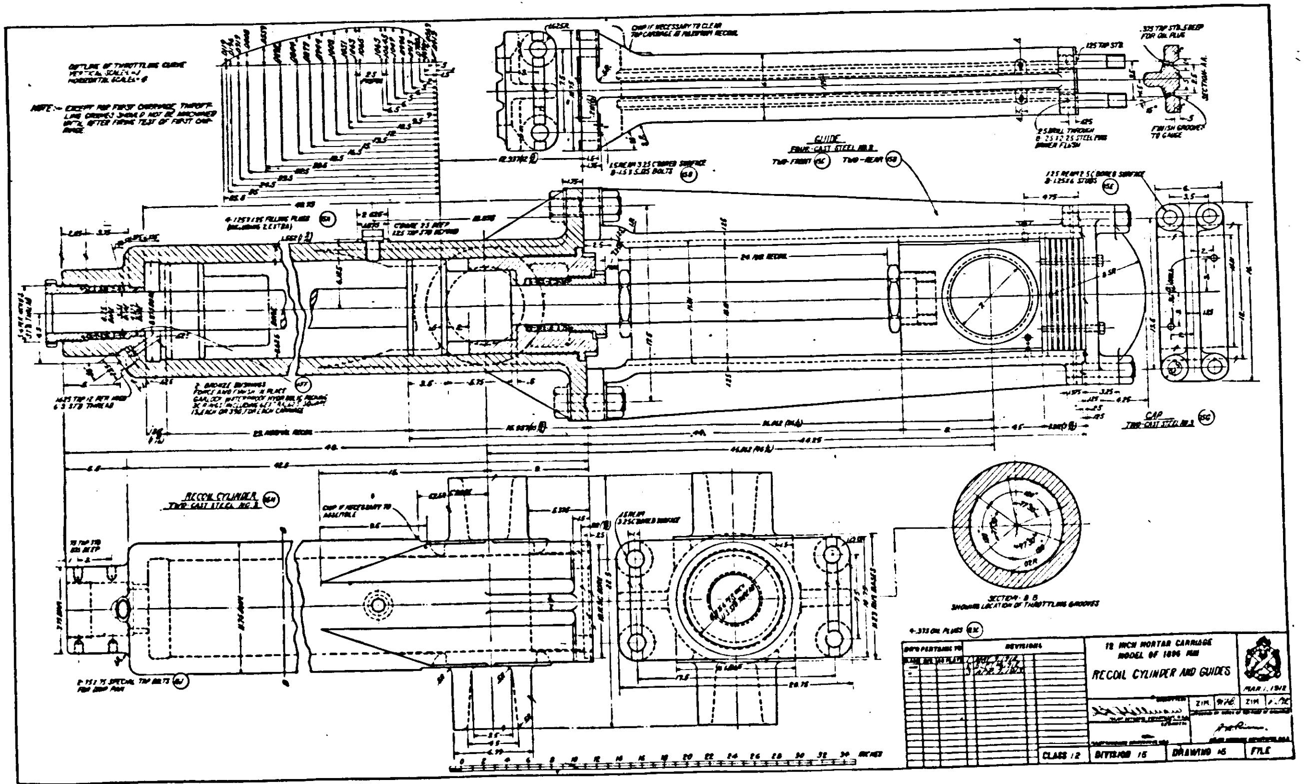
438. *Chassis or top carriage E.*—The chassis or top carriage, Plate 220, comprises a racer which has incorporated in it the slightly raised trunnion supports carrying the oscillating recoil cylinders. It has bolted to its bottom side forward two brackets carrying the oscillating spring support. The spring support may be considered a part of the top carriage likewise. The yoke pinned to the brackets at its front is solid and of cast steel and has machined trunnion supports which encircle the gun trunnions. The racer proper is of the common box section and is machined to a conical bearing for the conical rollers. The inner surface of the extension of its outer web is machined to serve as a bearing for the pintle machined on the

PLATE 221.



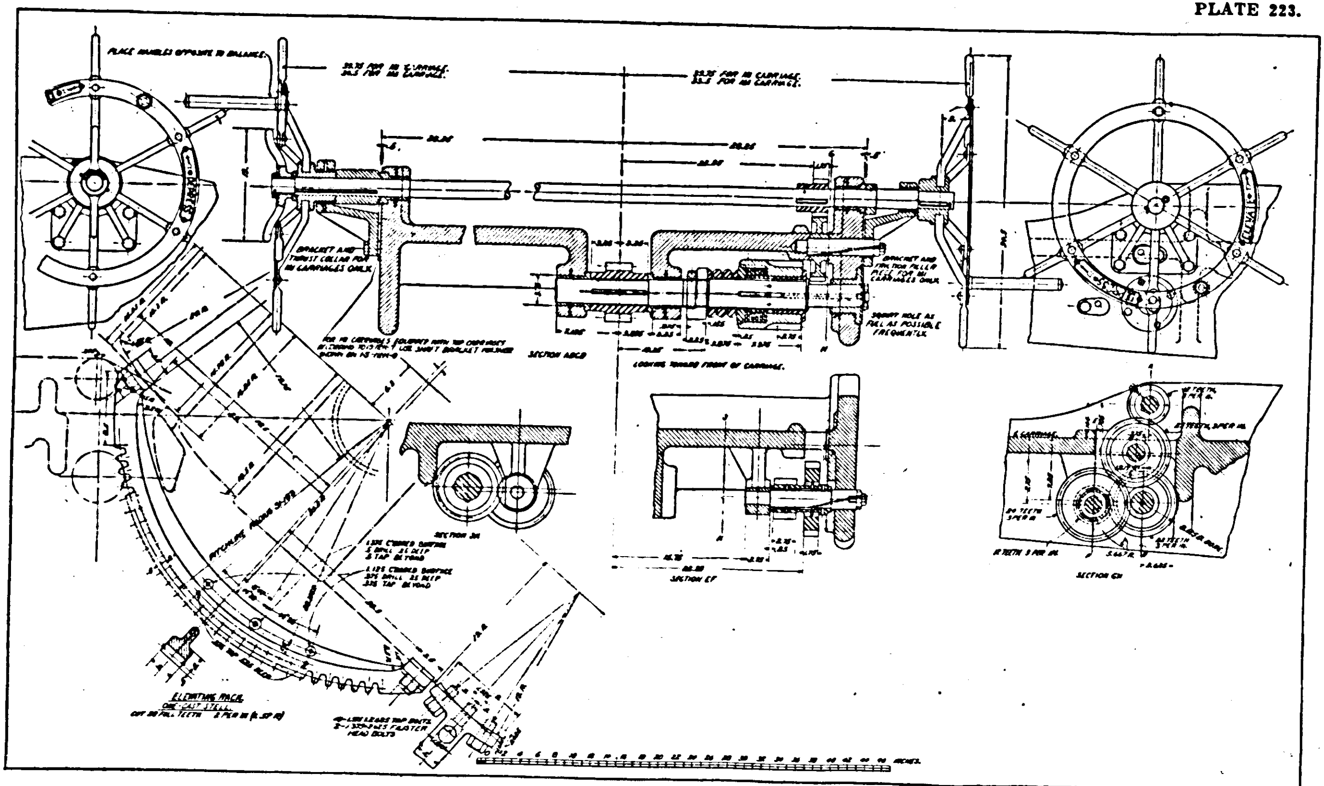
RECOIL MECHANISM, 12-INCH MORTAR CARRIAGE, MODEL OF 1896 MI.

PLATE 222.



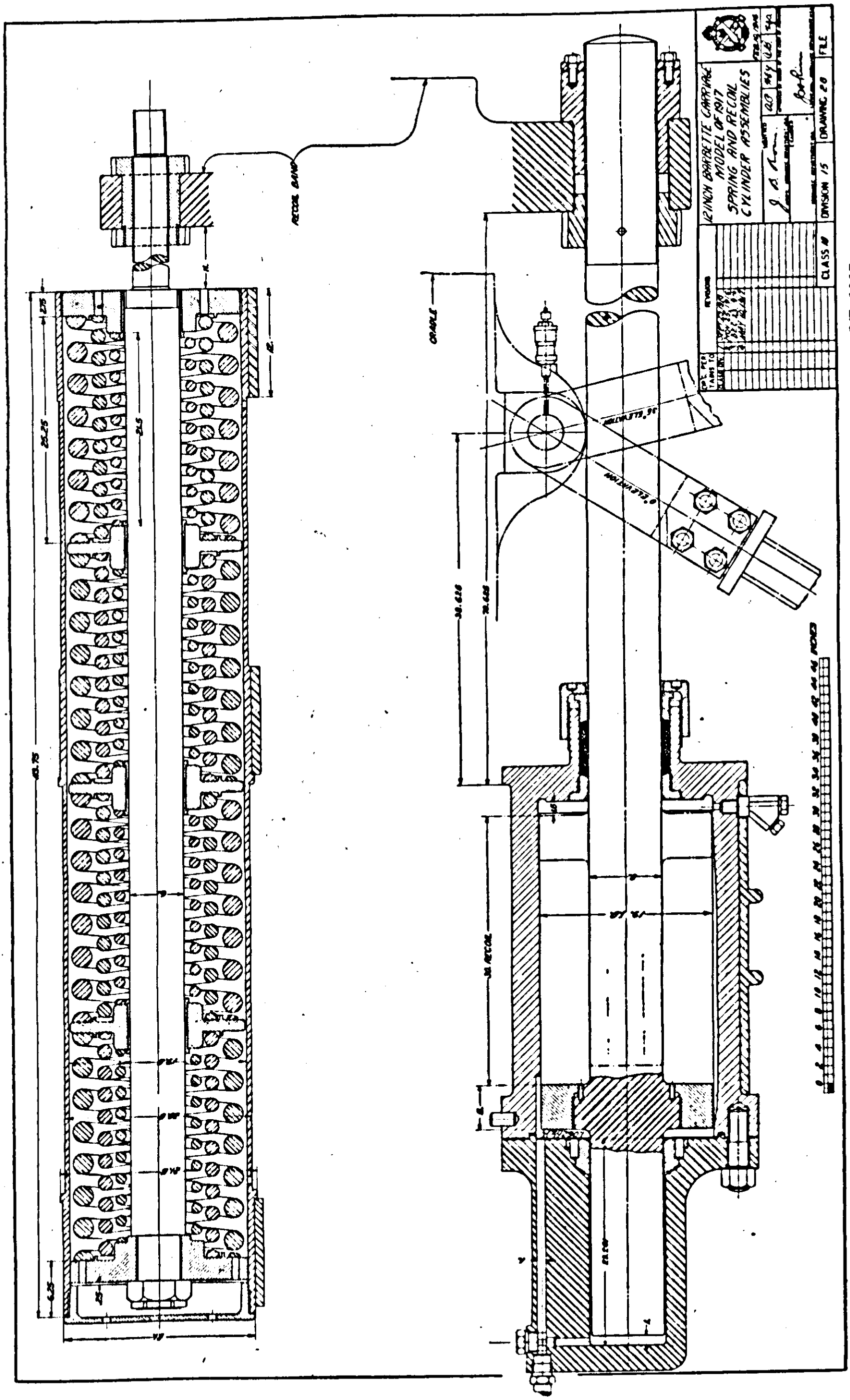
RECOIL MECHANISM OF THE 1912 MORTAR ON 1896 MIII MODEL CARRIAGE.

PLATE 223.



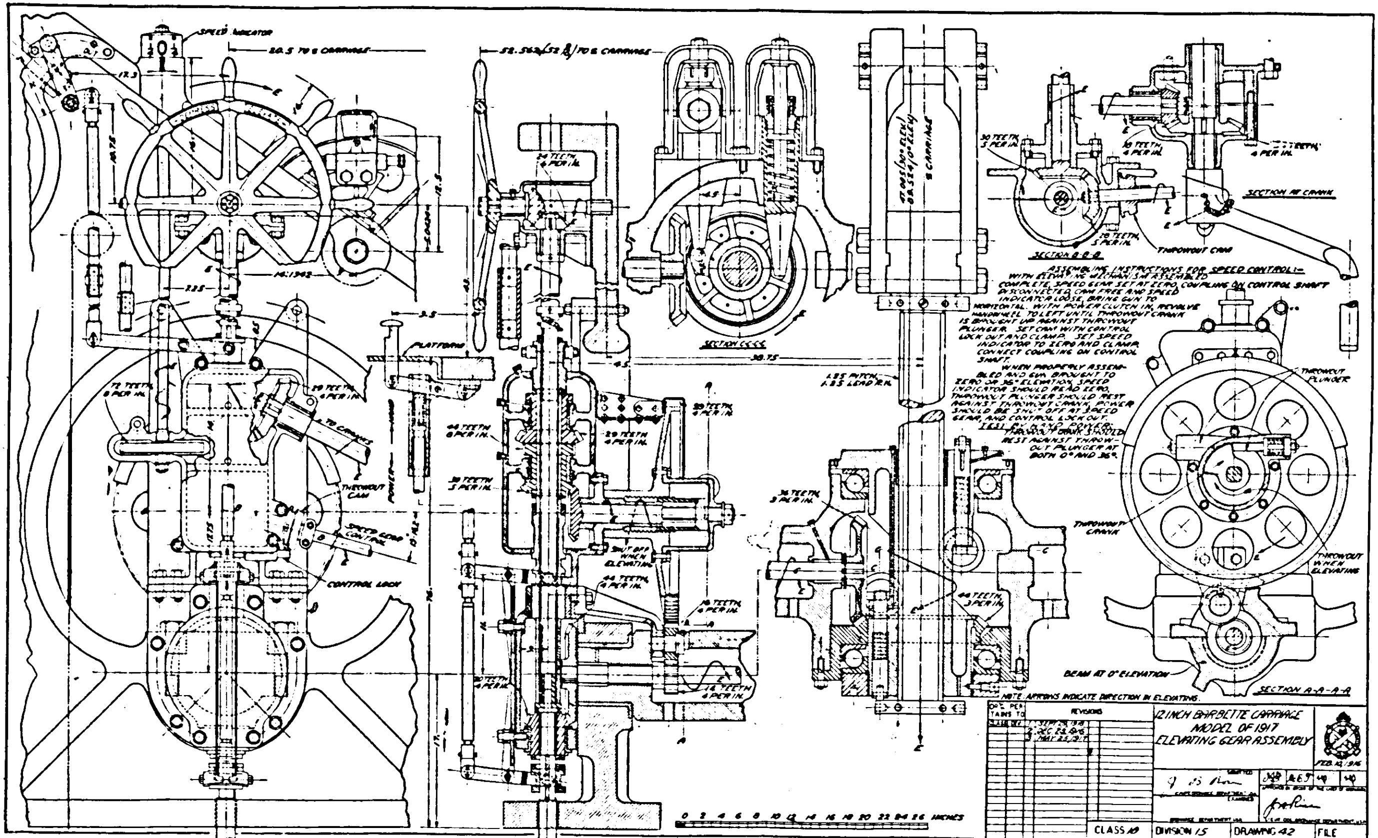
ELEVATING MECHANISM OF THE 1896 MODEL OF 12-INCH MORTAR CARRIAGE.

PLATE 227.



RECOIL AND RECUPERATOR SYSTEM OF THE 12-INCH BARBETTE CARRIAGE OF 1917.

PLATE 228.



ELEVATING MECHANISM OF THE 1917 BARBETTE CARRIAGE FOR 12-INCH GUNS.

vertical intermediate pinion. This pinion is actuated in three ways, to be described later. The elevating nut and screw are supported in the elevating-screw beam, which is held in bearings in the side frames. Ball bearings are provided at both the upper and lower ends of the nut. Elevating is provided for between 0 degrees and 35 degrees, and the elevating screw is provided with stops at these limits. Buffer cylinders are provided to ease the action of the stops. The buffer cylinders are supported in yokes, which are bolted to the elevating-screw beam. Longitudinal grooves of varying depths are provided in the cylinders to regulate the flow of oil by the pistons. Steel springs are provided to return the pistons, and stuffing boxes and gaskets close the cylinders.

446. The elevating is accomplished in three ways:

1. Slow motion by handwheel.
2. Quick motion by elevating cranks.
3. By motor power.

For using the quick motion by the elevating cranks the operating lever is set at "In" on the clutch-stop plate. By means of the upper and lower connecting rods and the quick-motion fork the upper portion of the quick-motion clutch is pulled down against the strength of a spring and meshed with the lower portion. This is in turn meshed with the quick-motion upper bevel gear, which is bolted to the end of the quick-motion shaft, on the lower end of which is keyed the quick-motion lower bevel gear, which in turn is in mesh with the crank gear, which is keyed to the crank shaft. The crank itself is pinned on the shaft. The elevation is accomplished by turning the elevation cranks, the power being transmitted through the above-described chain of shafts and gears to the upper portion of the quick-motion clutch, which is keyed to the vertical shaft. This shaft is keyed inside of the control sleeve, which in turn is keyed to the hand clutch. The hand clutch is meshed with the vertical intermediate pinion, and from there the chain is as previously described.

447. For slow motion the operating lever is set at "Out," which disengages the lower portion of the quick-motion clutch, and thus omits all that chain of shafts and gears going to the cranks, but leaves the remainder the same. The handwheel is connected to the vertical shaft by the handwheel shaft and the bevel handwheel gears. For operating by power, the control sleeve is raised by one of the power-clutch forks, operated by a treadle on the platform, so as to mesh with the control-gear clutch and release from mesh with the vertical intermediate pinion. At the same time the power clutch is raised by the other power-clutch fork and meshed with the under side of the vertical intermediate pinion. The power clutch is keyed to the vertical power

shaft, which is connected to the "B" end of the elevating motor shaft by the power pinion and power gear.

448. The speed of elevation by power is controlled by a Waterbury hydraulic speed gear, by means of which the rotation of the "B" end of the shaft may be varied from 0 to 800 revolutions per minute, while the speed of the "A" end is constant with the motor itself at 800 revolutions per minute. The adjustment is made by the speed-gear control. After the power clutches are thrown in, if it is desired to elevate the handwheel is turned in the proper direction to elevate and by a train of gears previously described motion is given to the control sleeve. This sleeve is now in mesh with the control-gear clutch, which, by means of the indicator gear and shaft, sets the speed indicator. At the same time another gear on the control-gear clutch is meshed with a bevel gear on the throw-out shaft. This same bevel gear is meshed with the upper control pinion, bolted to the upper end of the upper control shaft. The lower end of this shaft is connected by the beveled control gears to the control mechanism of the hydraulic speed gear, which is thus set to give the speed and direction indicated on the speed indicator. To stop elevating by power, the gun pointer simply moves the elevating handwheel back so that the indiactor reads 0. There is also an automatic mechanism to shut off when the limiting stops are reached. This is accomplished by means of the throw-out mechanism. Keyed to the horizontal shaft is a throw-out pinion, which is meshed through an idler to the throw-out gear. This gear turns freely on the throw-out shaft until either 0 degree or 35 degrees elevation is reached, when the throw-out crank fitted on the throw-out shaft comes against the throw-out plunger, which is bolted to the gear. The shaft is then turned by the gear, and, being in mesh with the upper control pinion and the control-gear clutch, it thus brings the control back to zero and shuts off the power from the power shaft, and at the same time sets the speed indicator to zero through the chains of gears and shifts previously described.

449. *Traversing mechanism.*—The traversing mechanism (Pl. 226) consists of the traversing rack in 10 segments attached to the base ring by 80 steel traversing-rack screws, the traversing pinion of steel on a vertical forged-steel shaft, provided with bearings in the traversing bracket, and rotating with the carriage, geared to the steel crank shafts which extend across the carriage, by means of a traversing-gear wheel and a crank pinion. The cranks are used for normal traversing. Slow-motion traversing is provided for at the telescopic sight by means of a vertical slow-motion shaft, which is in two parts, bolted by a slow-motion shaft coupling. The slow-motion shaft is geared to the handwheel shaft by means of the slow-motion gear and the handwheel pinion. The lower end of the slow-motion shaft is geared to the worm shaft by the slow-motion pinion

and the worm-shaft gear. The worm shaft is connected to the traversing shaft by means of a worm, which engages in a worm wheel provided with a multiple-disk friction drive. There are 10 friction disks, 5 steel disks keyed to the sleeve of the shaft, and 5 bronze disks keyed to the worm gear. A clutch, operated by a treadle on the platform, throws the slow motion in or out. Cast-steel gear cases are provided for all gears.

450. The azimuth circle consists of a bronze ring in eight sections. The sections are of T cross section for rigidity. Each section is riveted to a steel support. These supports are grooved so that the eight sections when bolted together form a hollow cylinder surrounding the traversing rollers and thus serving also as a dust guard. The outside of each support is stiffened by means of two stiffeners, which are steel angles, and are riveted to the supports. The sections are accurately bolted together by means of steel straps. The supports are bolted to the base ring by means of bases permanently bolted to the outside of the base ring. These bases are all steel angles. The circle is graduated in degrees, but not numbered until the carriage is in its emplacement.

451. A pointer case of cast steel is placed in the recess of the racer, which exposes the top of the circle; the pointer body is placed in the case and graduated and numbered as a subscale, to read to ten one-hundredths of a degree, and by means of a graduated thumb screw a reading of one one-hundredth of a degree can be obtained. The pointer is designed to permit final adjustment by means of set screws on the degree marks of the circle at the time the circle is numbered. The index is of German silver and is carried in a bronze slide. A cast-steel lid is provided for the case.

452. *Loading mechanism.*—See B, paragraph 326.

453. *Top carriage F.*—The top carriage, Plate 226, is composed of two main cast-steel side girders braced at the front by a heavy cast-steel transom, at the rear by a transom that serves as part of the working platform and mounted on a heavy cast-steel racer of box section. The side frames have attached to them a series of brackets on which the working platform is mounted and contain at their top two supports or trunnions for the cradle. The entire power mechanism for elevating and all of the gearing for traversing are mounted on this carriage. The racer, which is of a section slightly different from those already described, is machined on its under side to serve as a bearing for the conical rollers and on its inner surface to serve as a bearing against the pintle of the base. A series of brackets on the outside hook on a flange of the base ring, preventing overturning of the carriage on firing at low elevations.

454. *Base.*—The base ring, Plate 226, is made in two parts, and has bolted to its inner surface the traversing rack, is machined to

a conical bearing for the traversing rollers, and has a flange on its outer edge under which the racer clip-brackets are hooked to prevent overturning.

12. 12-INCH RIFLES, MODELS OF 1888 MI AND MII, ON BARBETTE CARRIAGE, MODEL OF 1892.

455. *Cannon.*—The number of C hoops has been successively reduced from 10 in the type gun to 6 in model of 1888, Plate 225, to 5 in model of 1888 MI, to 3 in model of 1888 MI½, and to 2 in model of 1888 MII. The D hoops have been reduced from 5 in the type gun to 2 in model of 1888 and of 1888 MI and to 1 in all later models. The B hoops have been reduced from 8 in the type gun to 4 in model of 1888 and to 3 in all later models except 1900, which has but 2. The A hoops have been reduced from 7 in the type gun to 5 in model of 1888, to 4 in model of 1888 MI, and to 3 in all later models except model of 1900, which has but 2.

456. *Breech mechanism.*—See D, paragraph 430. The breech mechanism is the same, except in dimensions, as that of the 10-inch gun of the same model, Plate 229, except that in the 12-inch gun ball bearings are introduced into the tray hinge to carry easily the greater weight, and 12-inch guns, model of 1888 mounted on disappearing carriages, model of 1896, have a modified form of tray lock latch handle, and that in the model of 1905 the number of turns of the operating crank and the number of teeth on the compound gear and worm wheel are increased over the corresponding number for 10-inch guns.

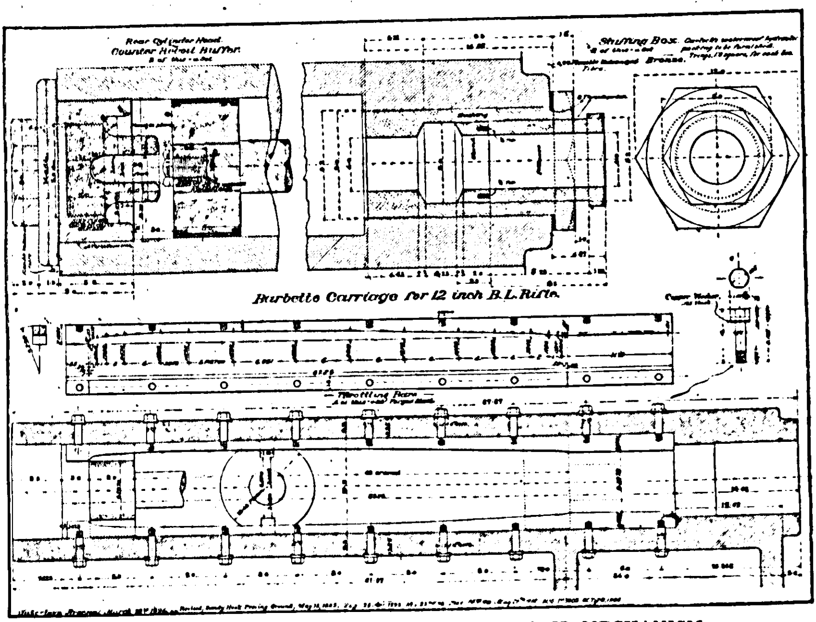
457. *Firing mechanism.*—See B, paragraph 287.

458. *Recoil mechanism F.*—This recoil mechanism comprises a top carriage which in turn supports the gun by its trunnions, Plate 230, and rests on either side on a series of rollers embodied in the chassis. The number of rollers on each side is nine. These rollers are mounted on pins through the webs of the chassis. The top carriage embodies two recoil cylinders the pistons of which are attached to the chassis at the front. The length of recoil is 48 inches, and as the gun is fired the top carriage rolls to the rear and up an incline of 4 degrees until it strikes a stop at the rear. As soon as the energy of recoil has been dissipated through the work done in forcing the weight of the gun and carriage up the incline and in forcing the oil through the orifices, the gun and carriage return to battery through the force of gravity. The recoil cylinders are shown on Plate 231, where it is seen that throttling bars are employed instead of grooves. A counter-recoil buffer of still a slightly different design from those already described is provided here. The principle of operation, however, is identical.

459. *Recuperator mechanism F.*—This is the first carriage in which the force of gravity has been employed exactly in this manner

to return the gun to battery. It will be recalled that in the case of the disappearing carriage the counterweight through which the axle of the gun levers pass and which supports the entire weight of the gun and the counterweight rolls up a slight incline as the gun recoils. The fact that that carriage is mounted on an incline of course facilitates the return of the gun to battery, but it will be remembered that the pull of the counterweight was depended upon to return the enormous weight of the gun to its firing position above the parapet. Since the elevation at which guns were operated at the time of the designing and construction of this carriage was relatively limited, it was feasible to employ this type of carriage. When the elevations were

PLATE 231.



BARBETTE CARRIAGE, MODEL OF 1892, RECOIL MECHANISM.

increased to 20 degrees, 30 degrees, and finally 45 degrees, this type of carriage became impracticable because of the extreme vertical component of the force of recoil, which produced tremendous stresses in the entire mount. As soon as the gun and top carriage have come to a stop in their recoil the force of gravity serves to pull them forward down the incline into battery. The energy of counter recoil, which is considerable by the time the gun is practically in battery, is dissipated through the counter-recoil buffer, already described in the recoil mechanism.

460. *Elevating mechanism.*—There is a feature of the elevating mechanism to which attention might be called, although it presents

nothing in design that one might be interested in remembering. Pointing in elevation is obtained by a forged-steel rack bolted to the gun. A pinion mounted on a short cross shaft engages the rack. On the outer end of this shaft there is keyed a cup-shaped friction clamp fitting over a corresponding shaped hub located on the outside of a worm gear mounted on the elevating pinion shaft and brought to a bearing in its seat by a nut on the end of the shaft. By this arrangement excessive stress on the elevating mechanism is relieved during firing. This worm gear engages in a worm splined upon a vertical shaft, on the lower end of which is splined a bevel gear which engages with a second bevel gear upon the main elevating shaft, which runs parallel to the top surface of the right chassis rail. This second bevel gear slides upon the squared section of this shaft, being carried back and forth during the recoil of the top carriage. The front end of the main elevating shaft is connected with the elevating handwheels, one on each side of the carriage, by spiral gears and a through shaft. To indicate the amount of elevation of the gun a toothed gear rack is bolted to the left trunnion. This actuates a toothed pinion carrying the elevation pointer. The pitch diameter of the gear rack and pinion are to each other as 5 to 1; thus the pointer moves through an angle five times as great as that which the gun moves through. This makes the graduations on the bronze arc larger in proportion. The arc is bolted to the top carriage through slotted holes so as to permit of adjustment. The least reading is two minutes. The teeth of the rack are very accurately cut, and a spring is provided to take up backlash.

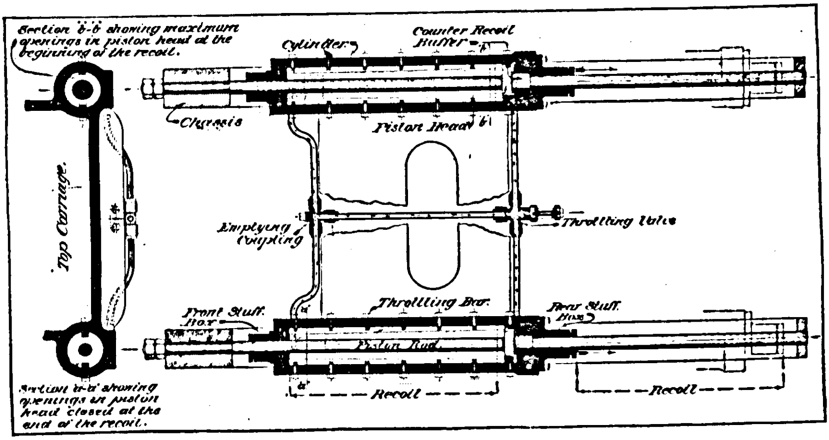
461. *Traversing mechanism.*—Two crank handles are attached to the traversing shaft and operated by men standing on a concrete platform. These handles actuate a train of gears engaging a traversing rack which is machined on the outer circumference of the base ring. The ratio of this mechanism is one turn of the handwheel to 2.43 degrees in traverse.

462. *Loading mechanism.*—At the rear of the left chassis a crane for raising the projectile to the gun is supported in lugs cast on the chassis. The fall of the hoisting tackle leads from the crane sheave over guide sheaves to a drum mounted on a short shaft passing through the left chassis. Motion is communicated to the drum by spur gears from a parallel short shaft carrying the hoisting crank. A pawl engaging in a ratchet wheel on the crank shaft holds the projectile at any height. Seven shot tongs, one tray, and three ammunition trucks are provided with each carriage.

463. *Chassis.*—The chassis is made in three main sections comprising two side girders fitted to a racer, together with a structural steel loading platform at the rear. The racer is machined to a cone

bolt, which is seated in the breech face of the gun, its lower end being engaged in a notch into the periphery of the block. The short arm of the bell crank is arranged to fit into a notch cut into a cap fitted to the upper end of the hinge pin. The bell crank is provided with an operating handle for controlling the locking bolt. Before an attempt is made to open the breech mechanism, the block-locking bolt must be tripped from its seat in the block. After it is tripped the breechblock can be rotated. During the rotation and translation of the block the short arm of the bell-crank lever is out of its notch in the hinge-pin cap and is bearing against the periphery of the cap. This holds or supports the locking bolt in its upward or unlocked position, in order that there will be no interference between the locking bolt and the breechblock when closing the latter. The locking

PLATE 233.



RECOIL SYSTEM FOR DISAPPEARING CARRIAGES.

bolt works automatically when closing the breech mechanism, but must be operated by hand before the breechblock can be rotated for opening the same. The obturator is of the same construction as for the model of 1888 guns, except the ball bearings are used instead of spindle washers.

469. *Firing mechanism.*—See B, paragraph 287.

470. *Recoil mechanism.*—See B, paragraph 292, and table of data. This carriage is designed to mount guns of either the model of 1895 or the model of 1900, Plates 232 and 233. It embodies many additions and improvements on the previous models, the principal ones of which are general stiffening of the structure, the turntable being 3 inches deeper; a sighting platform along each side of the carriage, accessible by ladders in front and in rear; sight-laying apparatus, with new 3-inch telescopic sight arranged to be used by a man on the

sighting platform, who has under his own immediate control all operations of laying and firing, if desired; electric motor as well as hand appliances for the operations of traversing, elevating, depressing, and retracting the gun; the control of the electric-motor equipment from either the sighting or the working platform; connections for electric firing either by the man at the sight or by the battery commander (in salvo); the addition of a safety appliance for electric firing and of a lanyard attachment, which prevent firing before the gun is in battery; improved lubricating appliances; and new counter-recoil buffers, which permit of sufficient counterweight being used to bring the gun into battery in from five and one-half to seven seconds.

471. *Recuperator, elevating, traversing, and loading mechanism, chassis, and base.*—See B, paragraphs 307, 310, 319, 326, 328, and 329, respectively.

14. 12-INCH GUN, MODEL OF 1895, ON DISAPPEARING CARRIAGE, MODEL OF 1897.

472. This gun and carriage are illustrated on Plate 234.

473. *Cannon.*—See paragraph 465.

474. *Breech mechanism.*—See paragraph 467.

475. *Firing, recoil, recuperator, elevating, traversing, and loading mechanism, chassis, and base.*—See B, paragraphs 258, 287, 307, 319, 326, and 329, respectively.

15. 12-INCH GUNS, MODELS OF 1888 AND 1895, ON DISAPPEARING CARRIAGE, MODEL OF 1896.

476. This gun and carriage are illustrated on Plates 225 and 235.

477. *Cannon.*—See paragraph 455.

478. *Breech mechanism.*—See paragraphs 456 and 467.

479. *Firing mechanism.*—See B, paragraph 287.

480. *Recoil mechanism.*—There are a few minor differences between the design of this carriage and the designs of models of 1897 and 1901. The carriage is illustrated on Plate 235. The essential differences between the recoil mechanism of this carriage and those already described is in the rollers on which the top carriage rests. In Plate 234 it will be observed that the rollers are carried between distance bars and some of them have gears on their ends which engage with racks on the chassis and carriage and the rollers recoil or move to the rear with the top carriage, although at only half the rate. In this carriage, Plate 235, the rolls are incorporated in the chassis as in the case of the barbette carriage, Plate 230. The incline up which the carriage recoils is 2 degrees in this case, as against 1 degree for some of the other carriages. The mounting of

the rolls on individual spindles as shown here involves greater friction than in the design already described where the friction is of the rolling type and is a minimum. For description of the other features of the recoil-mechanism see B, paragraph 292.

481. *Recuperator mechanism.*—See B, paragraph 307.

482. *Elevating mechanism.*—In variance with the elevating arm and screws of the carriages of models 1897 and 1901, Plates 232 and 234, this mechanism consists of an elevating arm, the lower part of which is divided and each fork end attached by trunnions to a sliding elevating rack which are in turn connected to two handwheels by means of a gear train. An elevating shaft 10 feet 9 inches long is mounted through both chassis in roller bearings and has handwheels on each end. This shaft carries one of a set of miters, the other being keyed to the end of an elevating worm shaft. A worm, which is forged in one with its shaft, turns in bearings in the worm-wheel case, which is bolted to the racer. It is provided with a ball-thrust bearing between the worm and the sleeve nut, the latter holding it in place. This worm engages in the teeth of a bronze worm wheel, which is held between two cast-iron friction disks, the whole being inclosed in the worm-wheel case. These friction disks are keyed to the elevating pinion shaft and turn with it, but have a motion along its length. Their contact with the worm wheel may be tightened or loosened by means of the two clamping nuts on the pinion shaft. The pinion shaft is supported by and turns in roller bearings in each chassis. This shaft carries a pinion near each end, which engages in the teeth of an elevating rack. When the handwheel is turned, the motion is transmitted through the elevating miters and elevating worm to the worm wheel and the pinion shaft, which turns with it. The pinions turn with the pinion shaft, and their teeth engaging in the teeth of the elevating racks raise or lower the racks which are trunnioned to the fork ends of the elevating arm, thus elevating or depressing the gun. The elevation disk turning with the pinion shaft indicates the elevation.

483. *Traversing mechanism.*—See B, paragraph 319.

484. *Loading mechanism.*—See B, paragraph 326.

485. *Chassis.*—The chassis of this carriage differs in principle from those already described, in that the recoil rollers are housed in them instead of rolling on them. It will be observed also by comparing this carriage with the model of 1897 that no working platform is attached to the racer of this carriage.

486. *Base.*—See B, paragraph 329.

16. 12-INCH 35-CALIBER GUN, MODEL OF 1895, ON RAILWAY CARRIAGE, MODEL OF 1918.

487. This gun and carriage are illustrated on Plates 225, 236, 237, and 238.

488. This mount is built on a design almost identical with the design of the mounts on which the French have placed 305 and 304 millimeter guns and 370-millimeter howitzers. Modifications were made in the French design to adapt the mount to American manufacture and the American guns. It was designed by the Societe des Batignolles in France, during the latter part of 1914, and the first mount was tested at the Railway Artillery Camp in January or February of 1915. All mounts of this type rendered most excellent service throughout the war, proving definitely the merit of the design. The original American plan was to mount a number of 10-inch 34-caliber guns, models of 1888, 1888 Mark I, and 1888 Mark II, on the same design of carriage. This has not and likely will not be done. It can be done at any time without great difficulty simply by providing a new cradle with decreased inside diameter and a slight modification of the throttling grooves and the recoil cylinders.

489. *Cannon.*—The guns that are being used with these mounts are 12-inch, models of 1895 and 1895 Mark I, all of 35-caliber length. These guns are provided with the interrupted-thread type of breechblock which is fitted with a mechanical firing mechanism. The guns are provided with heavy splines on top and bottom, which not only prevent rotation of the gun on firing, but likewise carry the entire weight of the gun in the cradle; that is, the gun does not touch the cradle except in the splineways. This is not considered good design, but the French practice was followed in preference to making any radical modifications in their design at a time when it was imperative that the guns be mounted with the least possible delay. Difficulties already experienced in proof firing indicate that unusually fine machine work is required on the splines and splineways to prevent excessive friction and sticking of the gun before it has returned entirely to battery.

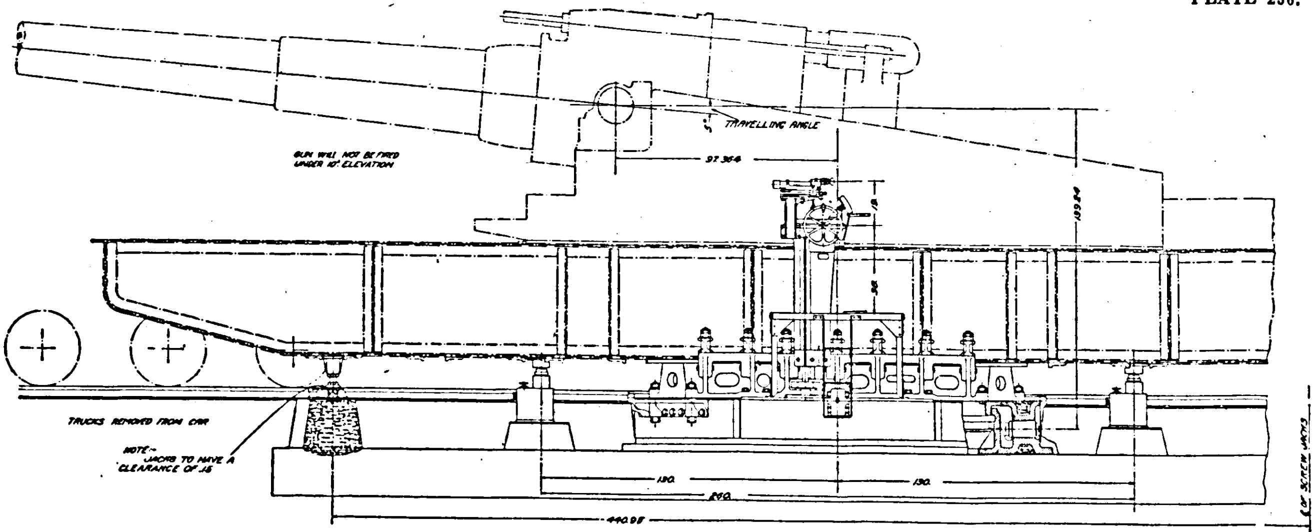
490. *Breech mechanism.*—See C, paragraph 343.

491. *Firing mechanism.*—See B, paragraph 287.

492. *Recoil mechanism.*—There are two recoil cylinders of this type attached to the bottom of the cradle. The length of recoil is about 900 millimeters, and no pit is required under the mount for firing to the highest elevation.

493. *Recuperator mechanism.*—See A, paragraph 261. The air required for the charging of the pneumatic recuperator, which in this case is a single cylinder on the top of the cradle, is furnished in steel bottles. For field service extra bottles are ordinarily carried on the mount.

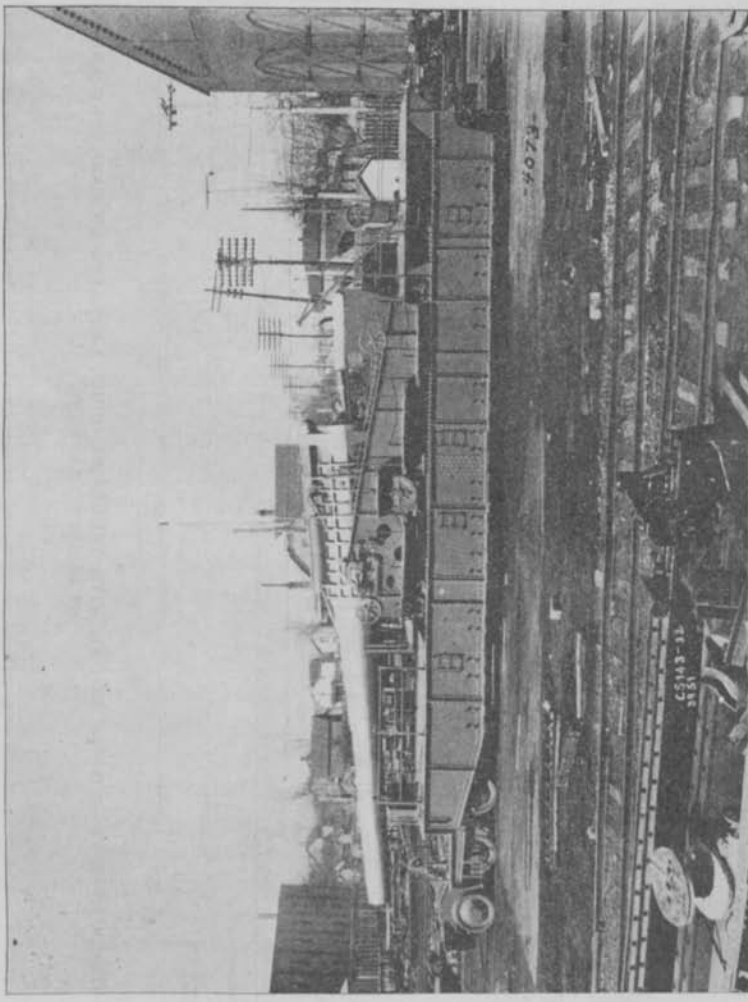
PLATE 236.



12-INCH BATIGNOLLE TYPE RAILWAY MOUNT, WITH TRUCKS REMOVED, EMPLACED ON BASE RING AND RACER FOR 360 DEGREE TRAVERSE.

494. *Elevating mechanism.*—It is possible to elevate the 12-inch gun from —5 degrees to +36 degrees. The elevating mechanism is in duplicate, with a rack attached to each side of the cradle and pinions connecting through slip-friction devices, worm and worm wheels, spur gears, a shaft, miter gears, and chains to the handwheels.

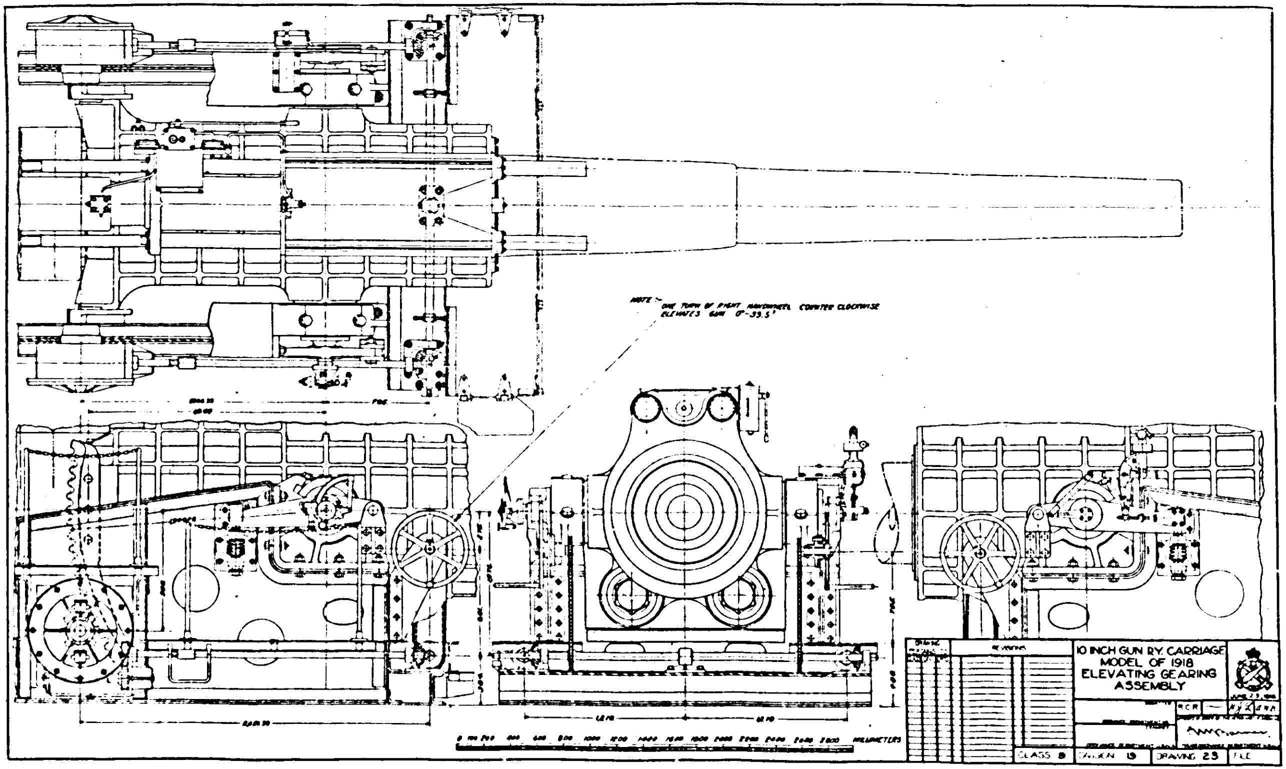
PLATE 237.



BATIGNOLLE TYPE RAILWAY MOUNT, WITH 12-INCH GUN, IN TRAVELING POSITION.

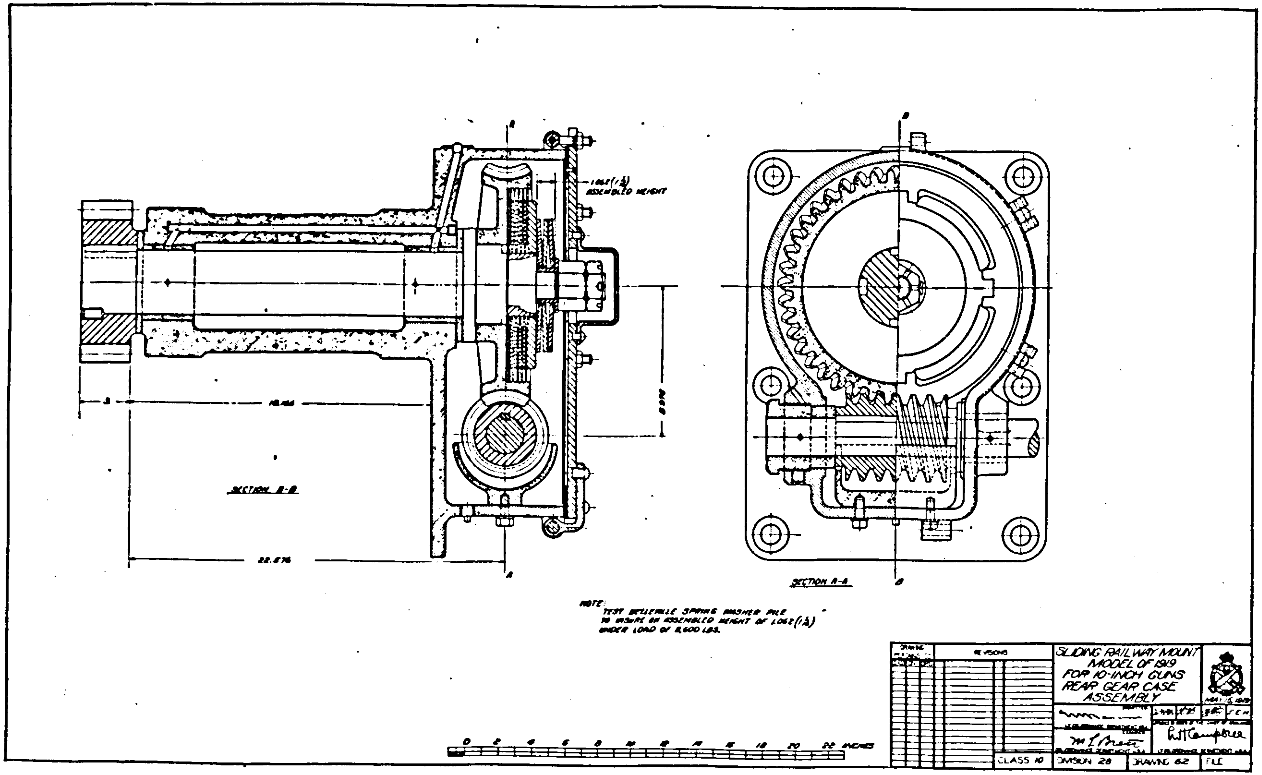
This mechanism is shown in detail on Plate 238. Antifriction devices of the lever design are included in the mechanism. This can be seen in the view at the right on Plate 238. The slip-friction devices are a part of the worm wheels shown on Plate 239, and in design are practically identical with that used on the 10-inch sliding mount. For easy elevating of the gun, the antifriction device is kept so adjusted

PLATE 238.



ELEVATING MECHANISM, ANTI-FRICTION AND RECOIL SYSTEM OF THE BATIGNOLLE TYPE OF RAILWAY MOUNT.

PLATE 239.



SLIP FRICTION DEVICE OF THE BATIGNOLLE ELEVATING MECHANISM.

that a 0.002 thickness gauge can be inserted under the main trunnion. It will be observed on Plate 238 that the two mechanisms are rigidly connected by a cross shaft on which the chain sprockets of each are mounted. One turn of the wheel moves the gun through 35 minutes in elevation.

495. *Traversing mechanism.*—Reference to Plate 237 will show that this mount comprises a top carriage, in which the gun is swung by means of the trunnions of the cradle, and a car body made up of two plate girders, together with numerous connecting transoms. The top carriage can be rotated about a front pintle to the extent of 5 degrees on each side of the center line by means of a traversing mechanism comprising a rack attached to the car body and a pinion and train of gears on the top carriage leading to the traversing handwheels. This provision is made for the service of the mount in the field. After some of the mounts had been completed it was proposed to attach to the bottom of the car body a racer from the 10-inch disappearing carriage, model of 1896. This adaptation has been made, and the mount, which was originally intended for field service, is now adapted to seacoast service through the incorporation of the disappearing carriage racer and base ring, the latter set in concrete. When the mount is being used for seacoast service, the top carriage is locked in its mid-position and a traversing mechanism similar to that described under B is employed, and through it the mount may be traversed to the extent of 360 degrees.

496. *Loading mechanism E.*—The loading mechanism proper, Plate 237, comprises a jib crane, ammunition table, and one-man tray. The projectile is picked up from a platform built around the emplacement or from the ground by means of the crane, transferred to the table, and is then rammed into the gun over the intervening tray by four men.

497. *Top carriage G.*—If we include in this case all above the base we find that the top carriage comprises the gun carriage, car body, and racer. The gun carriage includes the recoil and elevating mechanisms and two structural steel side frames with their connecting transoms in which these parts are assembled. This carriage is pivoted on the main girders by a heavy pintle which takes the horizontal component of the shock of firing, though normally the weight is supported on a smaller spring support pintle to reduce the friction of traversing. The car body comprises two plain plate girders of quite ordinary design connected by suitable transoms and provided with an operating platform at the rear.

498. *Base.*—Since we are describing this mount here as a seacoast weapon, no description will be given of the special firing platform which is provided for the service of the mount in the field. Those interested in a description of this field platform may refer to Rail-

way Artillery, Volume I, page 199. It has been mentioned before that in adapting this mount to seacoast service the racer and base ring of a disappearing carriage were used. The reader is referred to the description of such a racer and base ring as given under B, paragraph 329.

17. 12-INCH 10-CALIBER MORTAR ON RAILWAY MOUNT, MODEL OF 1918.

499. This gun and carriage are illustrated on Plates 218, 240, and 241.

500. *Cannon.*—The piece used with this mount is the 12-inch coast-defense mortar, model 1890, Mark I, of 10-caliber length. It is provided with an interrupted-thread breechblock which is fitted with a mechanical firing mechanism. There are 72 grooves and the twist of the rifling is to the right, the pitch progressing from one turn in 40 calibers to one turn in 20 calibers.

501. *Breech mechanism.*—See D, paragraph 430.

502. *Firing mechanism.*—See B, paragraph 287.

503. *Recoil mechanism.*—See C, paragraph 334. There are two hydraulic cylinders attached to the bottom of the cradle.

504. *Recuperator mechanism.*—See A, paragraph 261. This carriage is provided with a single recuperator cylinder mounted on the top of the cradle.

505. *Elevating mechanism.*—Elevation from —5 degrees to 65 degrees is secured through a segmental circular rack attached to the bottom of the cradle, a pinion meshing with this, a slip-friction device, worm wheel and worm, and a set of bevel gears leading to the handwheel. Any excessive thrust due to fire causes slipping in the friction device and can not impose excessive strain on the gears. One turn of the handwheel moves the mortar through 1.004 degrees in elevation.

506. *Traversing mechanism.*—The traversing mechanism of this mount provides for a total movement of 360 degrees, as with the 8-inch carriage. Gun and carriage are carried in cast-steel side frames on a racer casting, which is supported by conical traversing rollers. A complete circular rack is mounted on the base ring; a pinion of the traversing mechanism which is mounted on the racer meshes with this rack. This pinion connects through a vertical shaft, worm, and worm wheel with the operating handwheel. Any strain from the pressure of the projectile against the lands of the gun in firing is taken up as thrust on the worm. An azimuth circle with a pointer is provided for reading changes in azimuth. One turn of the handwheel moves the mortar through 0.837 degrees in azimuth.

507. *Loading mechanism.*—See D, paragraph 415.

PLATE 244.

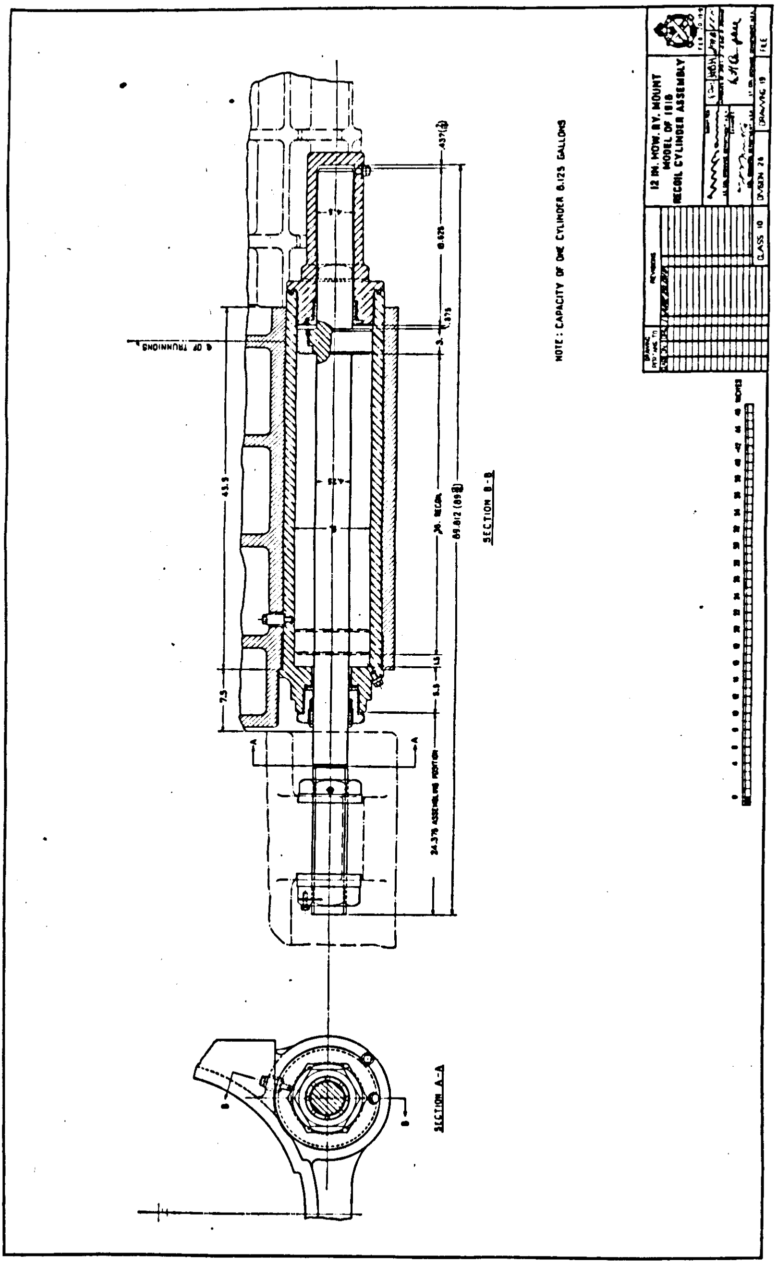

12 IN. HOW. RY. MOUNT
MODEL OF 1918
RECOIL CYLINDER ASSEMBLY
NOTE: CAPACITY OF ONE CYLINDER 6.125 GALLONS
SECTION B-B
SECTION A-A
℄ OF TRUNNIONS
24.375 ASSEMBLING POSITION
CLASS 10
DIVISION 26
DRAWING 19
FILE

PLATE 245.

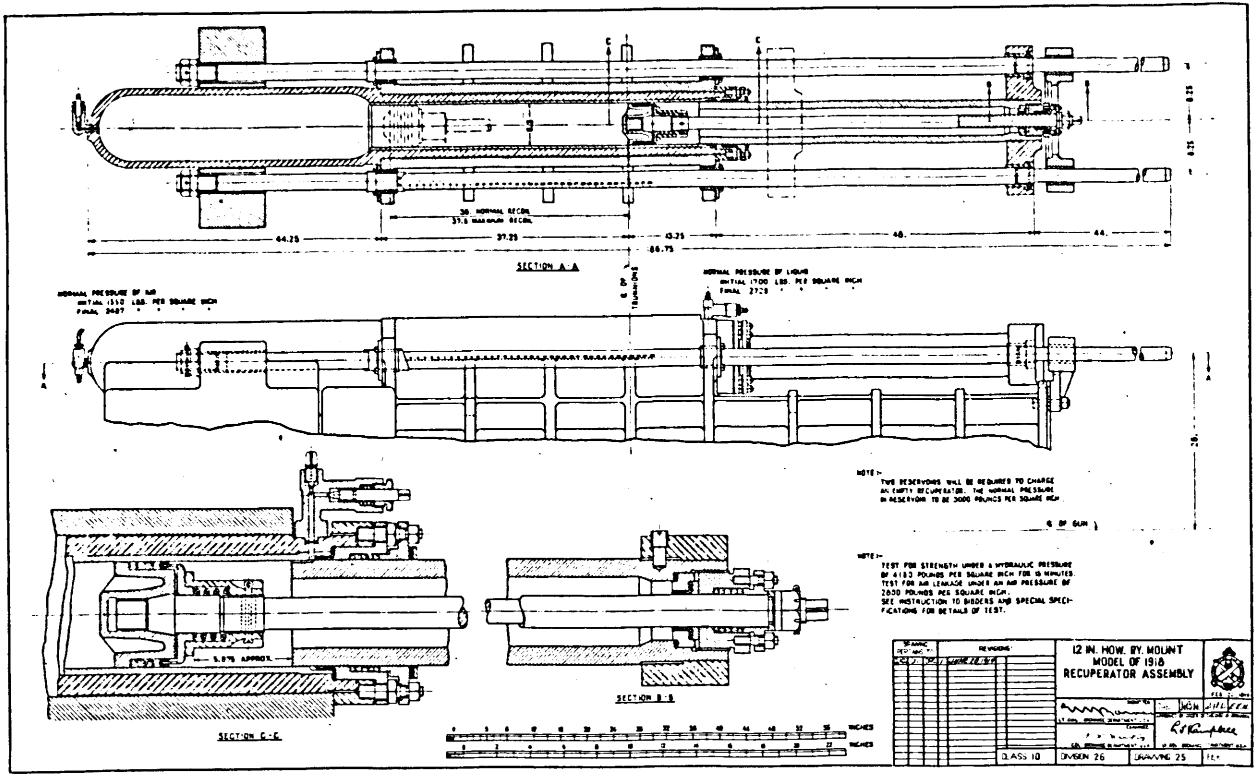

SECTION A-A
NORMAL PRESSURE OF AIR
INITIAL 1550 LBS. PER SQUARE INCH
FINAL 3487
NORMAL PRESSURE OF LIQUID
INITIAL 1700 LBS. PER SQUARE INCH
FINAL 2728
NOTE:-
TWO RESERVOIRS WILL BE REQUIRED TO CHARGE AN EMPTY RECUPERATOR. THE NORMAL PRESSURE IN RESERVOIR TO BE 3000 POUNDS PER SQUARE INCH.
NOTE:-
TEST FOR STRENGTH UNDER A HYDRAULIC PRESSURE OF 4183 POUNDS PER SQUARE INCH FOR 15 MINUTES.
TEST FOR AIR LEAKAGE UNDER AN AIR PRESSURE OF 2800 POUNDS PER SQUARE INCH.
SEE INSTRUCTION TO BIDDERS AND SPECIAL SPECIFICATIONS FOR DETAILS OF TEST.
SECTION C-C
SECTION B-B
12 IN. HOW. RY. MOUNT
MODEL OF 1918
RECUPERATOR ASSEMBLY
REVISIONS
CLASS 10
DIVISION 26
DRAWING 25

PLATE 246.

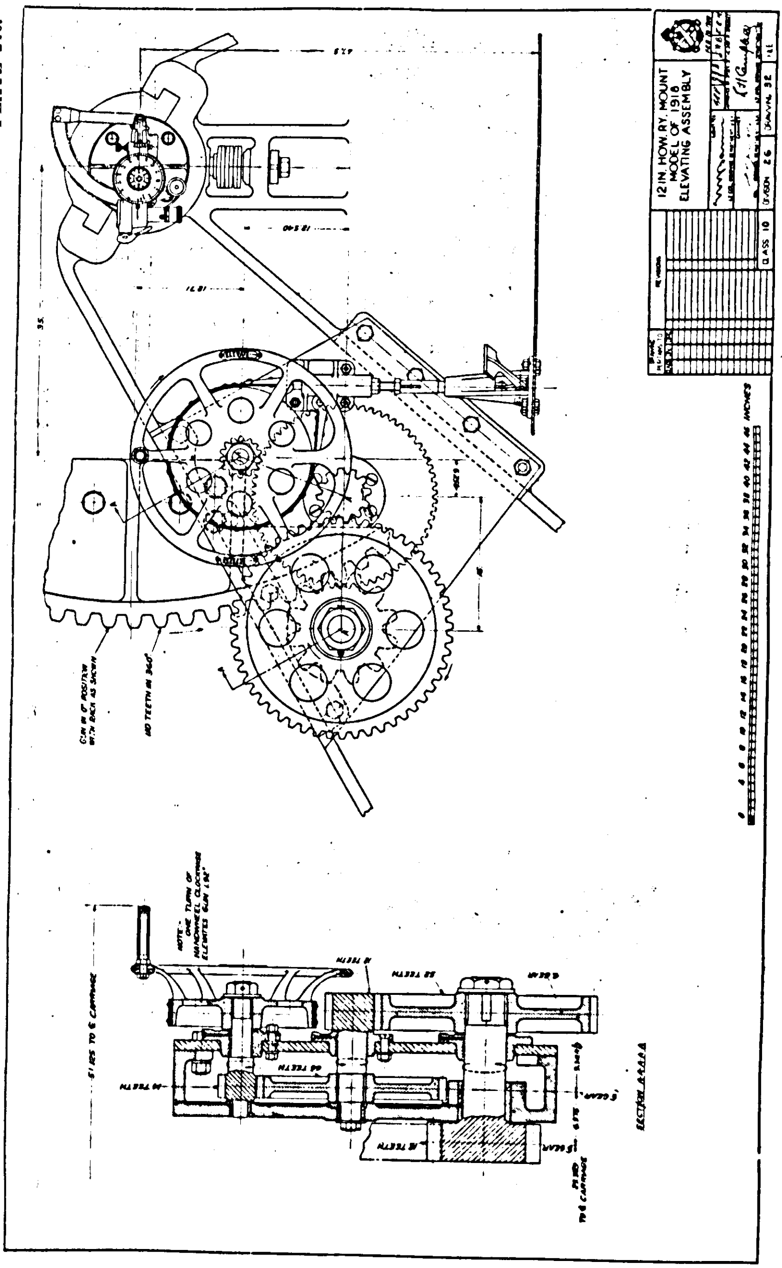

12 IN. HOW. RY. MOUNT
MODEL OF 1918
ELEVATING ASSEMBLY
SECTION A-A

PLATE 247.

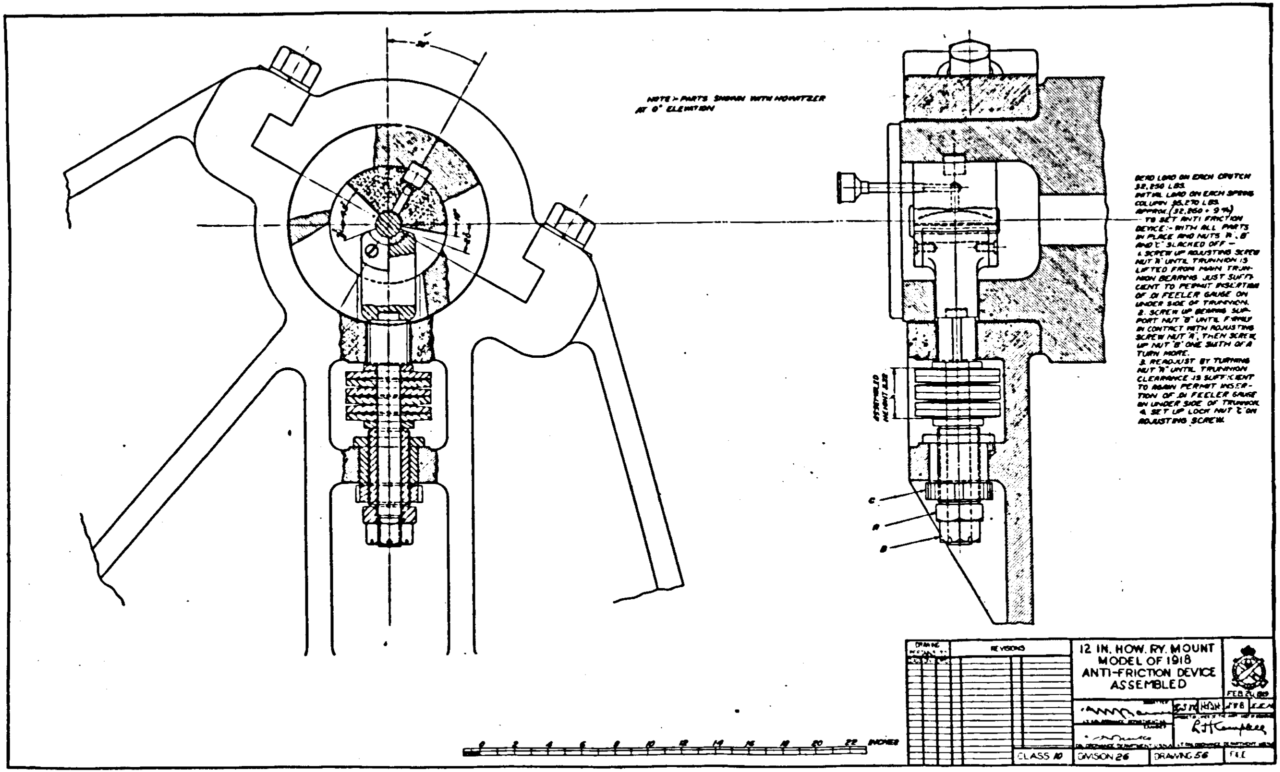
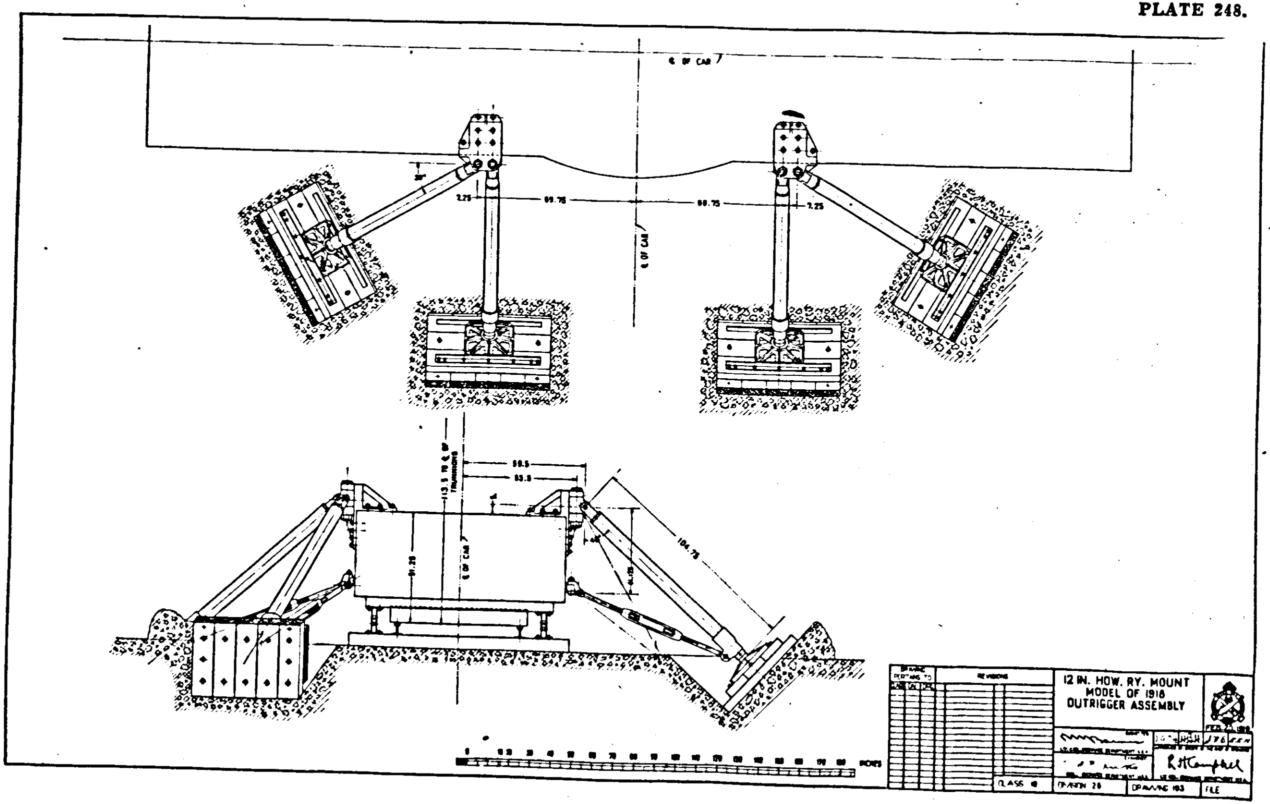
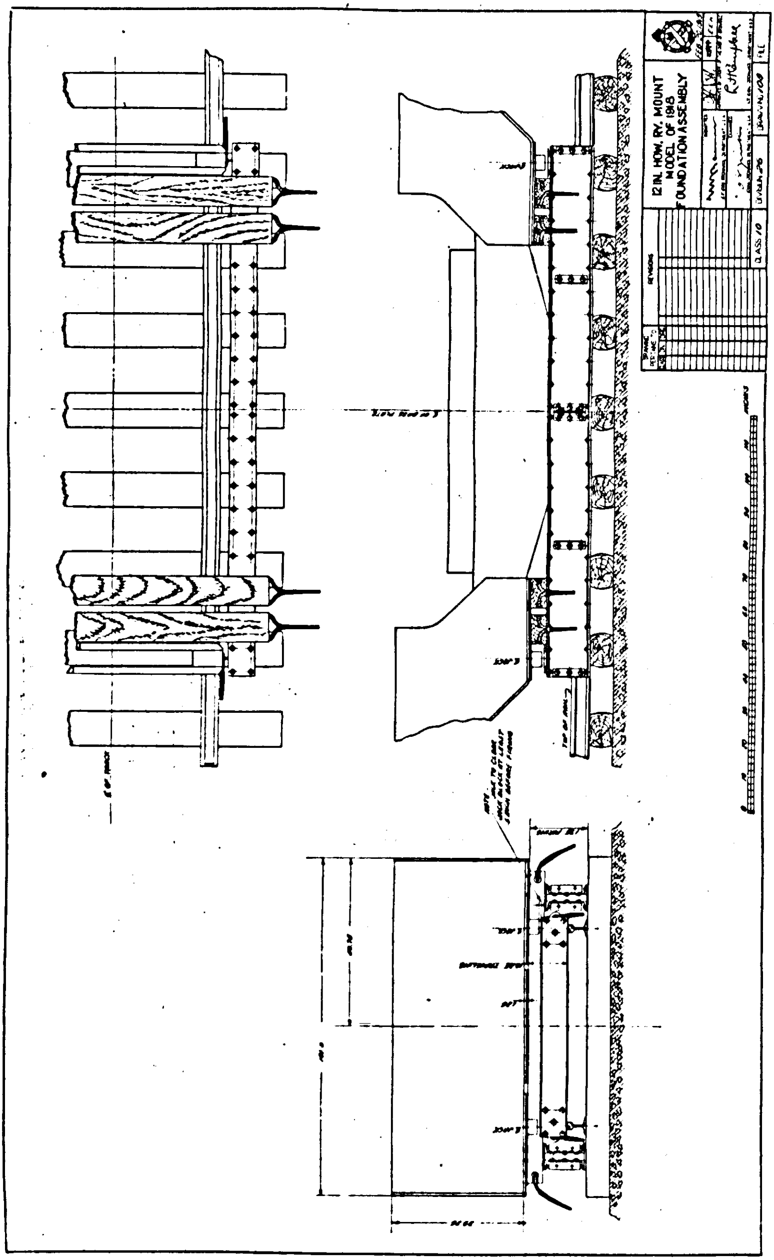

NOTE :- PARTS SHOWN WITH HOWITZER AT 0° ELEVATION
DEAD LOAD ON EACH CRUTCH 32,250 LBS.
INITIAL LOAD ON EACH SPRING COLUMN 35,270 LBS. APPROX. (32,250 + 9%)
TO SET ANTI FRICTION DEVICE :- WITH ALL PARTS IN PLACE AND NUTS "A", "B" AND "C" SLACKED OFF —
1. SCREW UP ADJUSTING SCREW NUT "A" UNTIL TRUNNION IS LIFTED FROM MAIN TRUNNION BEARING JUST SUFFICIENT TO PERMIT INSERTION OF .01 FEELER GAUGE ON UNDER SIDE OF TRUNNION.
2. SCREW UP BEARING SUPPORT NUT "B" UNTIL FIRMLY IN CONTACT WITH ADJUSTING SCREW NUT "A", THEN SCREW UP NUT "B" ONE SIXTH OF A TURN MORE.
3. READJUST BY TURNING NUT "A" UNTIL TRUNNION CLEARANCE IS SUFFICIENT TO AGAIN PERMIT INSERTION OF .01 FEELER GAUGE ON UNDER SIDE OF TRUNNION.
4. SET UP LOCK NUT "C" ON ADJUSTING SCREW.
C
A
B
ASSEMBLED HEIGHT
INCHES
REVISIONS
12 IN. HOW. RY. MOUNT MODEL OF 1918 ANTI-FRICTION DEVICE ASSEMBLED
FEB 24 1919
CLASS 10
DIVISION 26
DRAWING 56

PLATE 248.



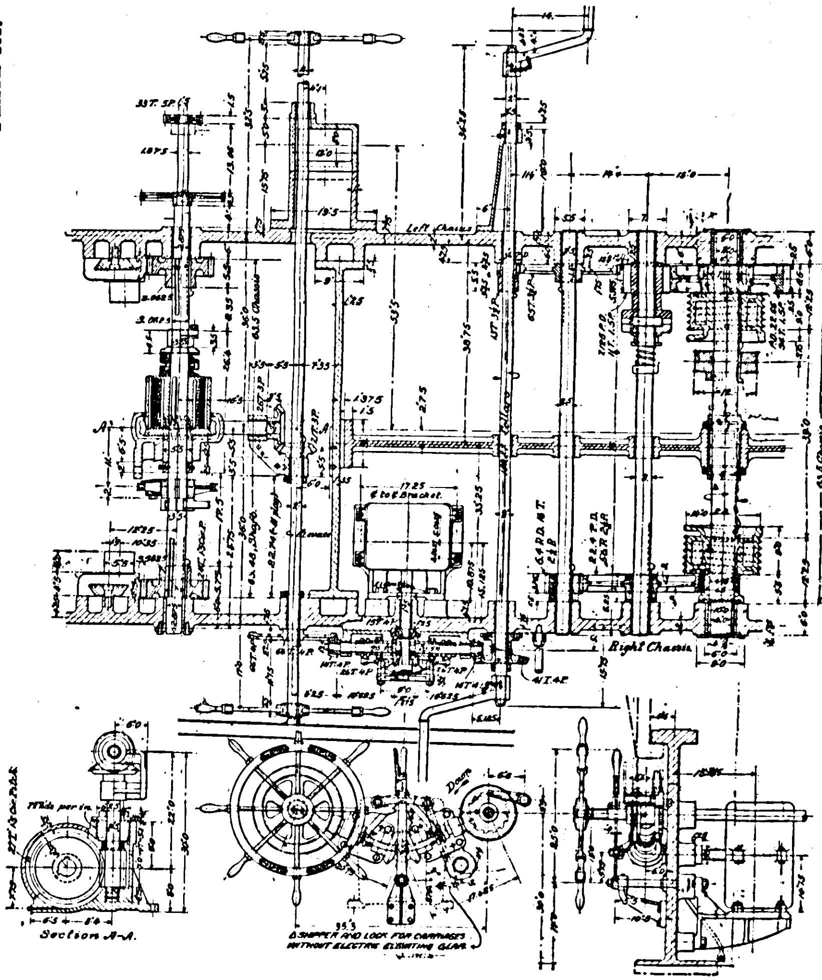
℄ OF CAR
℄ OF CAR
2.25
99.75
99.75
2.25
30°
113.5 TO ℄ OF TRUNNIONS
99.5
93.8
104.75
℄ OF CAR
INCHES
12 IN. HOW. RY. MOUNT
MODEL OF 1918
OUTRIGGER ASSEMBLY
REVISIONS
CLASS 10
DIVISION 28
DRAWING 193
FILE

PLATE 249.



526. *Recoil mechanism.*—See B, paragraph 292. The carriage is modified from previous models for the 10-inch guns, as follows: Increased weight and stiffness throughout; addition of a sighting platform along each side of the gun, accessible from the front or rear by ladders; addition of direct-sighting gear with 3-inch telescopic sight of largely increased efficiency, the whole arranged to give

PLATE 252.



ELEVATING AND RETRACTING MECHANISM OF THE 10-INCH DISAPPEARING CARRIAGE, MODEL OF 1901.

the gunner at the sight immediate control of the laying and firing, if desired; addition of electric gear for laying and retracting the gun, giving control from either the sighting or the working platforms; addition of traversing brake; electric firing and lighting apparatus; and counter-recoil buffers, which permit the use of sufficient counterweight to accomplish the counter recoil in from five to seven seconds.

527. *Recuperator, elevating, traversing, and loading mechanism, chassis, and base.*—See B, paragraphs 307, 310, 319, 326, 328, and 329, respectively.

20. 10-INCH RIFLES, MODELS OF 1888 AND 1895, ON A. R. F. DISAPPEARING CARRIAGE, MODEL OF 1896.

528. This gun and carriage are illustrated on Plates 250, 253, and 254.

529. *Cannon.*—See paragraphs 455 and 465.

530. *Breech mechanism.*—See paragraphs 456 and 467.

531. *Firing, recoil, and recuperator mechanism.*—See B, paragraphs 287, 292, and 307, respectively.

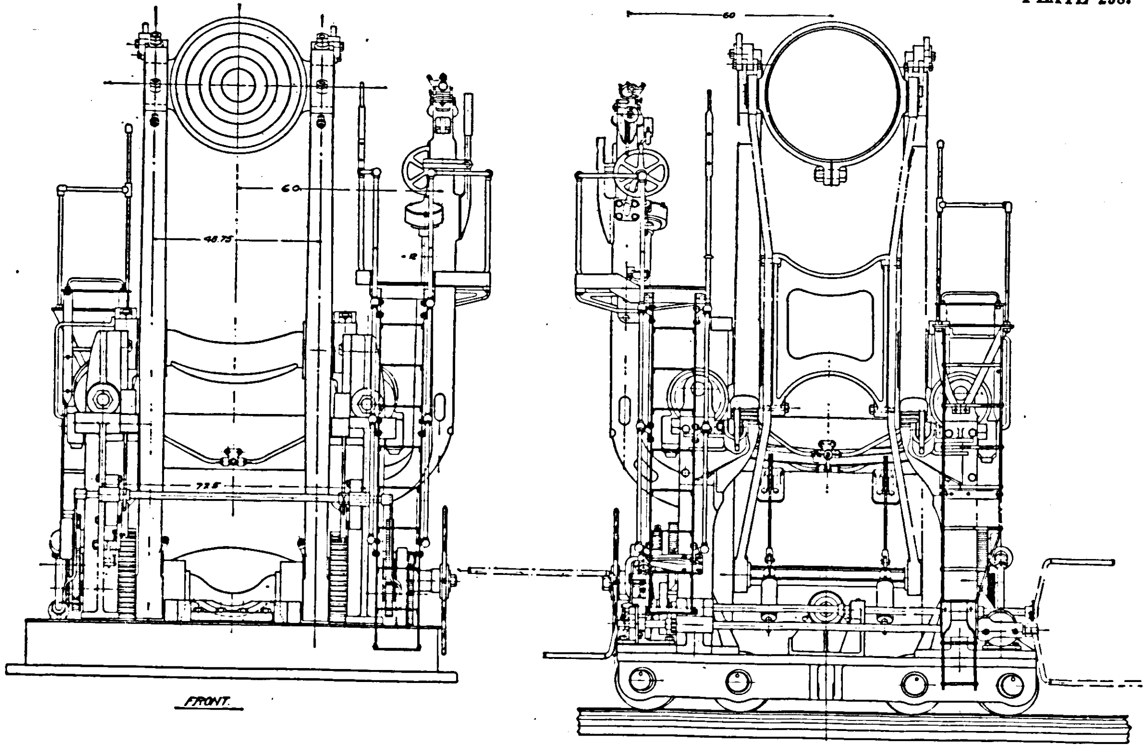
532. *Elevating mechanism.*—The elevating mechanism of this carriage differs from that of the model of 1901 10-inch gun just described in that the elevating arm has attached to it at the bottom a single elevating rack driven by a single pinion on the horizontal elevating shaft as against two racks on the 1901 carriage.

533. *Traversing mechanism.*—There is no essential difference between the traversing mechanism of this carriage and the mechanism described for the 16-inch carriage under B, paragraph 319. This carriage is afforded 360 degrees traverse, but simply through the provision of a base ring that permits of this extent of traverse rather than through a change of the traversing mechanism. Since the base, as will be described later, is double, there are two sets of traversing rollers, but each of the type already described. The traversing rack is attached to the extra base ring. The racers rest and rotate upon two concentric circles of live, conical, traversing rollers which are guided by trunnions with bearings in the distance rings. The outer traversing rollers are 48 in number and the inner ones 24, all made of forged steel. The distance rings for the exterior traversing rollers consist of two concentric circles of wrought iron, 1.125 by 4.5 inches in section, each made in four segments held together by fishplates and tap bolts. Twenty-four cast-iron separators, equally spaced, are secured to the distance rings by through bolts, thus keeping the rings together and permitting two rollers between each space thus formed. The distance rings for the inner traversing rollers are similar in construction to the outer rings, except that they are made in two segments, and being smaller are held in proper relative position by 12 cast-iron separators with through bolts.

534. *Loading mechanism.*—See B, paragraph 326.

535. *Chassis.*—Since there are two racers in this case, as against one for the previously described carriages, the chassis, which are of cast iron, are designed to be attached to both racers, the forward ends of the chassis being secured to the cast-steel segment of the exterior

PLATE 258.



10-INCH DISAPPEARING CARRIAGE, MODEL OF 1894 MI.

top carriage traverses to the rear are incorporated in the chassis, as with the 12-inch barbette carriage, model 1892. The use of an auxiliary base section with this carriage proved relatively undesirable, and the design was at once discontinued.

547. *Cannon.*—See paragraph 455.

548. *Breech mechanism.*—See paragraph 456.

549. *Firing, recoil, recuperator, and elevating mechanism.*—See B; paragraphs 287, 292, 307, and 310, respectively.

550. *Traversing mechanism.*—See B, paragraph 319. The system around the pintle consists of 20 forged-steel conical rollers, held in proper relative position by inner and outer wrought-iron distance rings, each forged in one piece. The rollers are forged with a trunnion at each end. The rings are united by separator braces, the bearings are slotted down through, and caps are screwed up under the trunnions of four rollers to hold the rings down in place, the whole being kept concentric with the pintle by flanges on the inner end of the rollers in centrifugal contact with the inner edge of roller paths. The system over the traverse rail consists of a transom supporting the rear end of chassis and carrying four pins upon which cast-steel wheels with conical rims revolve upon roller bearings.

551. A brass azimuth circle is recessed into the horizontal surface on the rear traverse rail. It is graduated in degrees in the shop. The figures for numbering the degree marks are added after the carriage has been mounted in its emplacement. The azimuth pointer body is fastened to the traverse-wheel transom by two screws through slotted holes in the body, thus allowing a slight adjustment in azimuth. The body carries the azimuth subscale, graduated to 0.05 of a degree and the micrometer head reading in hundredths of a degree. The micrometer head operates the index which moves across the subscale.

552. *Loading mechanism.*—See B, paragraph 326.

553. *Chassis.*—See paragraph 449.

554. *Base.*—The base ring is made of cast iron in a single piece. It is held in position on the foundation by sixteen 2-inch bolts. Sixteen screws are provided for leveling the base ring. These screw through holes in the base ring near the foundation bolt holes and bear against steel thrust plates. The lower roller path is machined on the upper face of the base ring. The male part of the pintle surface is machined on the outer surface of an annular flange extending upward from near the middle part of the base ring. A sheet-steel dust guard made in four sections is attached to the racer and extends downward to overlap the base ring, for protecting the traversing roller system from dirt and moisture. The annular flange forming

24. 8-INCH GUN, MODEL OF 1888, ON BARBETTE CARRIAGE, MODEL OF 1892.

567. This gun and carriage are illustrated on Plates 261, 262, and 263.

568. *Cannon.*—See Plate 261.

569. *Breech mechanism.*—See D, paragraph 430. This breech mechanism is illustrated on Plate 262. For description see paragraph 456.

570. *Firing mechanism.*—See B, paragraph 287.

571. *Recoil mechanism.*—See F, paragraph 458.

572. *Recuperator mechanism.*—See F, paragraph 459.

573. *Elevating mechanism.*—See D, paragraph 423.

574. *Traversing mechanism.*—See paragraph 563.

575. *Loading mechanism.*—See paragraph 462.

576. *Chassis.*—See paragraph 463.

577. *Base.*—See paragraph 464.

25. 8-INCH GUN, MODELS OF 1888 MI AND MII, ON DISAPPEARING CARRIAGE, MODEL OF 1896.

578. This gun and carriage are illustrated on Plates 264 and 265.

579. *Cannon.*—See Plate 261.

580. *Breech mechanism.*—See D, paragraph 430.

581. *Firing mechanism.*—See B, paragraph 287.

582. *Recoil, recuperator, elevating, traversing, and loading mechanism, chassis, and base.*—See B, paragraphs 292, 307, 310, 319, 326, 328, and 329, respectively.

26. 8-INCH 32-CALIBER GUN ON RAILWAY MOUNT, MODEL OF 1918.

583. This gun and carriage are illustrated on Plates 266, 267, and 268.

584. *Cannon.*—Seven different types of Army and Navy guns may be used on this mount:

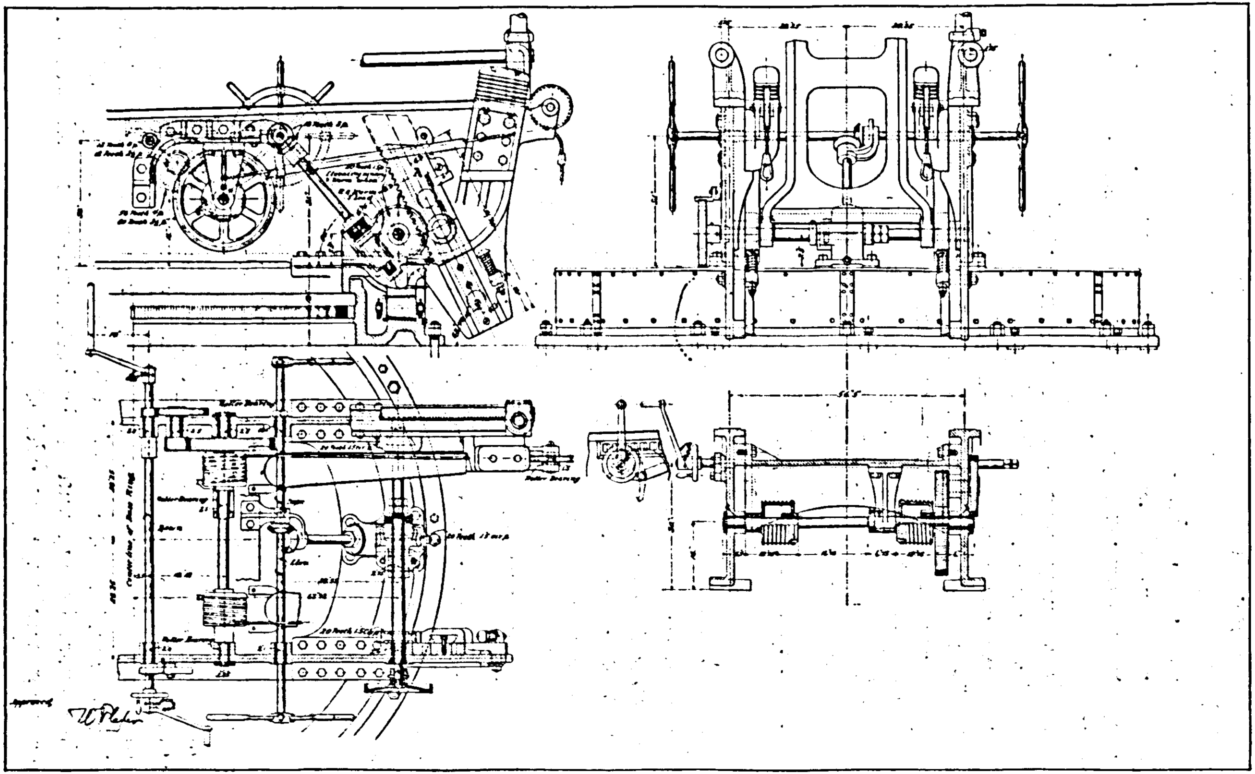
Army guns: Models of 1888, 1888 MI, 1888 MII.
Navy guns: Marks I, II, III, IV (16).

The Army guns are all 32 calibers in length, are equipped with uniform type of breech mechanism, and are mounted on model 1918 barbette carriages, having a standard type of cradle with hydraulic recoil and spring return system. The Navy guns vary from 30 to 40 caliber in length, are equipped with four different types of breech mechanism, and are mounted in barbette carriages, model 1918 MI, of the same general type as model 1918.

585. *Breech mechanism.*—See D, paragraph 430.

586. *Firing mechanism.*—See B; paragraph 287.

PLATE 265.



ELEVATING AND RETRACTING MECHANISM OF THE 8-INCH DISAPPEARING CARRIAGE, MODEL OF 1896.

PLATE 268.

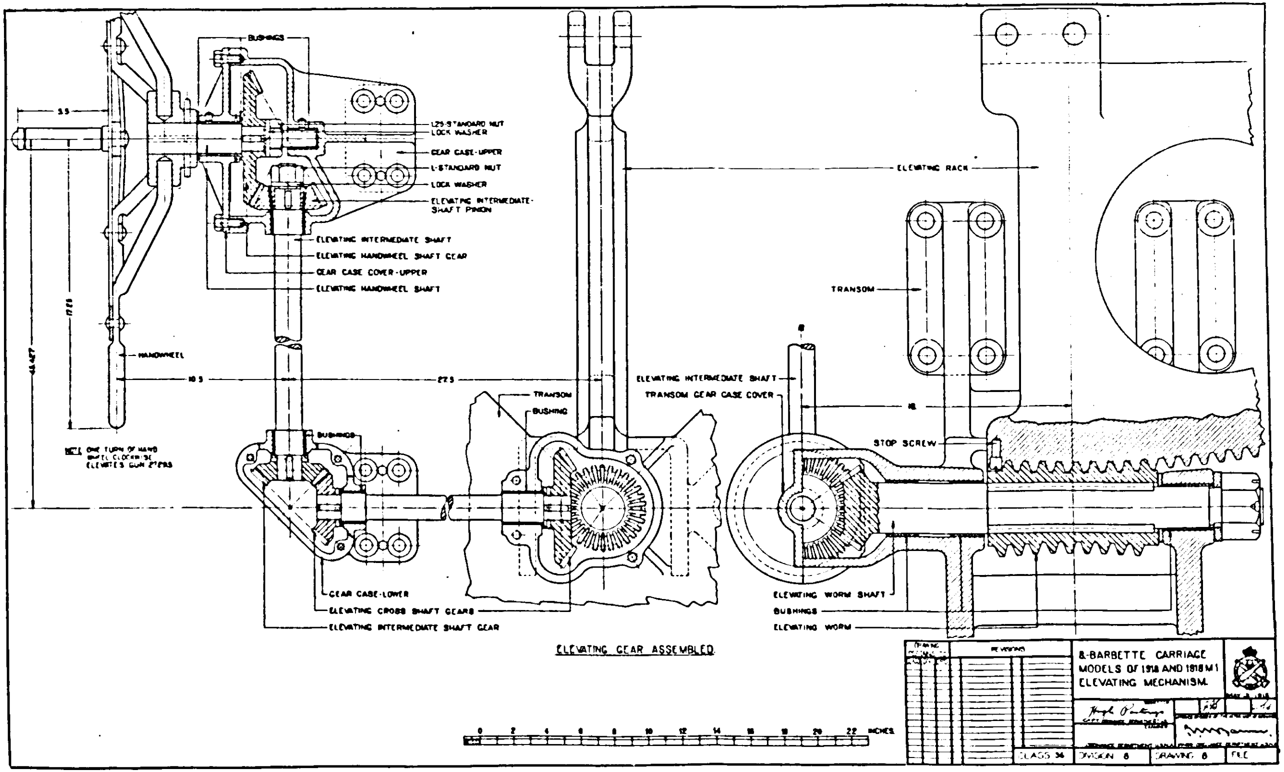
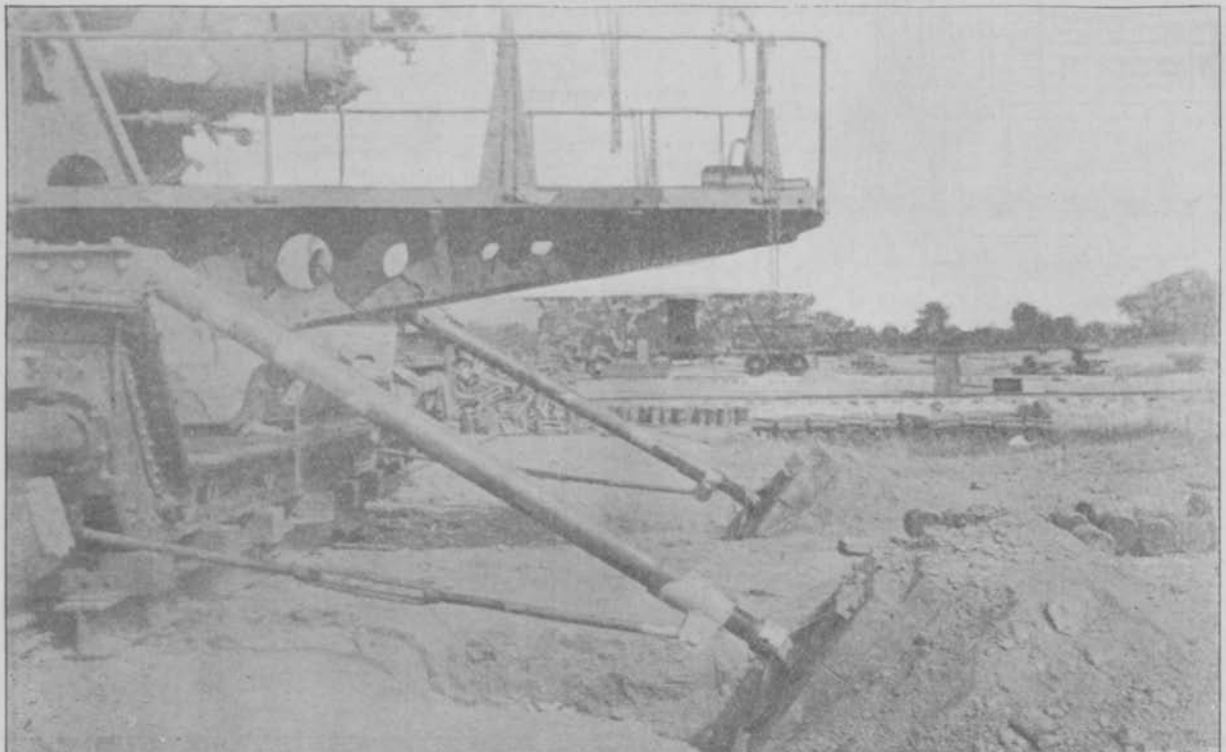

BUSHINGS
L25-STANDARD NUT
LOCK WASHER
GEAR CASE-UPPER
L-STANDARD NUT
LOCK WASHER
ELEVATING INTERMEDIATE-SHAFT PINION
ELEVATING INTERMEDIATE SHAFT
ELEVATING HANDWHEEL SHAFT GEAR
GEAR CASE COVER-UPPER
ELEVATING HANDWHEEL SHAFT
ELEVATING RACK
TRANSOM
HANDWHEEL
ELEVATING INTERMEDIATE SHAFT
TRANSOM GEAR CASE COVER
TRANSOM
BUSHING
STOP SCREW
BUSHINGS
GEAR CASE-LOWER
ELEVATING CROSS SHAFT GEARS
ELEVATING INTERMEDIATE SHAFT GEAR
ELEVATING WORM SHAFT
BUSHINGS
ELEVATING WORM
ELEVATING GEAR ASSEMBLED
INCHES
B-BARBETTE CARRIAGE MODELS OF 1918 AND 1918 M1 ELEVATING MECHANISM.
REVISIONS
CLASS 34
DIVISION 8
DRAWING 8
FILE

PLATE 269.



ANCHORAGE OF THE 8-INCH MOUNT, TOP CARRIAGE TRAVERSED TO FIRE AT RIGHT ANGLE TO TRACK.

a part of a longitudinal rack and serves to withdraw the block slightly. Under the gear segment, and between two lugs on the carrier, is mounted the pinion 35, which also has two sets of teeth adapted to mesh with those of the gear segment. The bottom portion of the pinion is squared and fits into the operating lever 37. The carrier contains the spindle stop 21, which serves also as a block stop. It passes through the guide cylinder as shown. The slot through which it passes embraces one-eighth of the circumference, and this portion is machined on a pitch equal to the pitch of the threads of the breechblock. The guide slot is L-shaped, the other portion going straight into the block and allowing longitudinal motion. When the operating lever is swung around to the right the bevel-gear part of the pinion meshes with the corresponding part of the carrier. This longitudinal motion of the breechblock is for the purpose of freeing the obturator so that the block may swing clear.

597. The breechblock of the model of 1905 gun, Plate 274, is conical, with the interior hollowed out; forming a central cylindrical stem, which is prolonged beyond the rear face of the block. Through the center of the stem is an axial hole for the reception of the obturator spindle and obturator spring. The front face of the block, for a short distance back, is reduced in diameter, leaving a space in the breech recess of the gun in which fouling may collect without interrupting the working of the block. On the outer surface of the block is cut a screw thread, with rounded top and bottom, the rear face of the thread more inclined to the surface of the block than the front face. This screw thread is divided circumferentially into 12 equal parts and the thread cut from alternate sectors. A stop groove is cut through the stem of the block to allow the spindle key to pass into the spindle groove. The spindle key thus serves the purpose of a breechblock stop. A notch is cut in the surface of the stem near its rear end in which the head of the safety plunger enters. An oil hole is cut radially in the nose of the block to provide for oiling the front face of the block. The parts of the obturator and the spindle spring are similar to those described for the 6-inch gun, model of 1903, paragraph 606.

598. *Firing mechanism.*—See B, paragraph 287.

599. *Recoil mechanism.*—See D, paragraph 359.

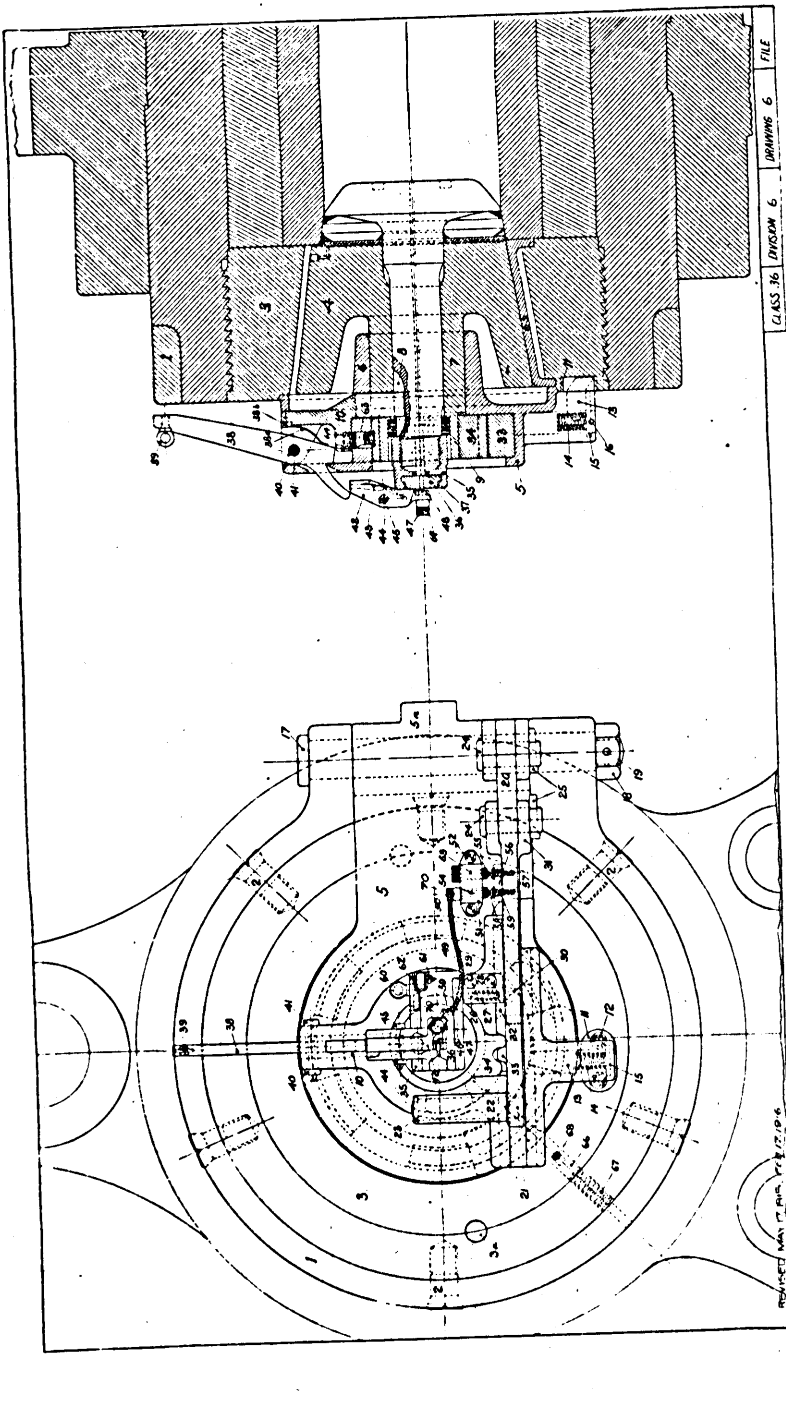
600. *Recuperator and elevating mechanisms.*—See C, paragraph 365 and 371, respectively.

601. *Traversing and loading mechanisms.*—See B, paragraphs 319 and 326, respectively.

602. *Chassis.*—See E, paragraph 438.

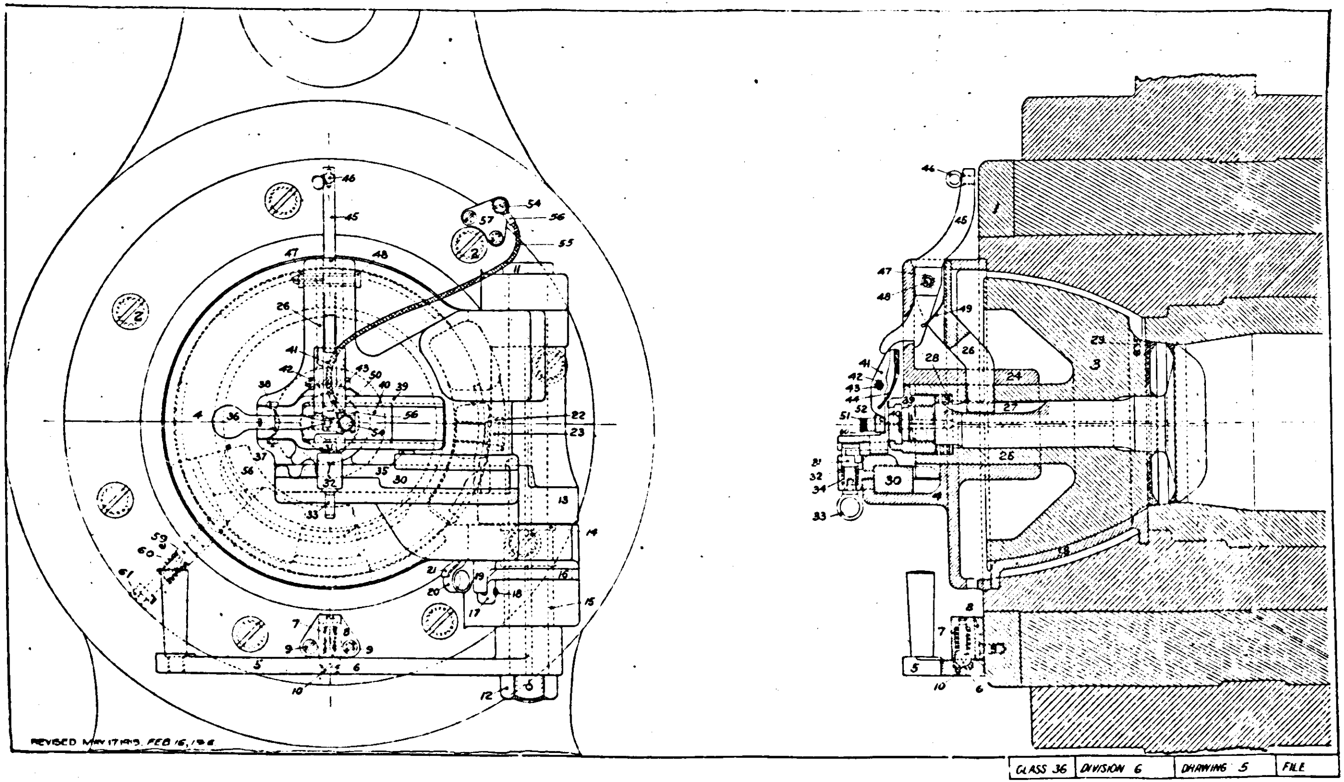
603. *Base.*—See B, paragraph 329.

PLATE 274.



BREECH MECHANISM OF THE 6-INCH GUN, MODEL OF 1905.

PLATE 275.



BREECH MECHANISM OF THE 6-INCH GUN, MODEL OF 1903.

28. 6-INCH GUNS, MODELS OF 1903, 1905, AND 1908, ON DISAPPEARING CARRIAGE, MODEL OF 1905 MI.

604. This gun and carriage are illustrated on Plates 273 and 276-277. Paragraph 593 under the 1905 carriage MII applies here as well.

605. *Cannon.*—The 6-inch model of 1903 is illustrated on Plate 273. As with the 1905 gun already described, it is of the built-up design, but differs as to powder chamber, breech, and the number of hoops.

606. *Breech mechanism.*—The breechblock of the model 1903 gun, Plate 275, is in the form of a truncated ogive, with the interior hollowed out, forming a central cylindrical stem, which is prolonged beyond the rear face of the block. Through the center of the stem is an axial hole for the reception of the obturator spindle and obturator spring. The front part of the block, for a short distance back, is reduced in diameter, leaving a space in the breech recess of the gun in which fouling may collect without interrupting the working of the block. On the outer surface of the block is cut a screw thread with rounded top and bottom, the rear face of the thread more inclined to the surface of the block than the front face. This screw thread is divided circumferentially into 12 equal parts and the thread cut from alternate sectors. An oil hole cut radially in the nose of the block and closed by a screw is provided for oiling the front face of the block. A stop groove is cut through the stem of the block to allow the spindle key to pass into the spindle groove The spindle key thus serves the purpose of a breechblock stop.

607. A roller is attached to the block by an axle screwed into the block. This roller works in the roller groove of the operating spool. entering the groove at the beginning of rotation in closing the breech and remaining in the groove until the end of rotation in opening the breech. The functions of the roller are to act as a lock to prevent rotation of the block under firing pressure, to give a slow and powerful thrust to the block at the beginning of rotation in opening the breech, and to complete rotation of block in closing the breech after rack tooth disengages. A translating groove is cut in the surface of the block. The translating stud on the operating spool works in this groove to cause translation of the block. On the rear end of the breechblock stem are two teeth which engage the tooth of the rack to cause rotation of the breechblock.

608. *Firing mechanism.*—See paragraph 627.

609. *Recoil mechanism.*—See D, paragraph 359. A comparison of this recoil mechanism, especially as to counterweight, Plate 276, with the counterweight of the 1905 MII carriage shown on Plate 270, reveals the fact that the counterweight here is built up practically to the top of the recoil cylinder. This is because of the increased

of an annular groove cut in the rear face of the block. This cylindrical surface is called the guide cylinder and the annular groove the guide groove of the block. That portion of the rear face of the block which lies outside of the guide groove is called the stop flange. When the block is withdrawn the stop flange strikes the bottom of the stop groove in the block carrier and limits the rearward motion of the block. The guide cylinder supports the breechblock in the carrier and guides it in its motions of rotation and translation. The guide flange of the block carrier fits into the guide groove of the block and assists in supporting and guiding the latter. Four oil holes are drilled radially from the exterior of the block to the bottom of the guide groove to facilitate oiling the bearing surfaces. These holes also act as air vents. An oil hole cut radially in the nose of the block and closed by a screw is provided for oiling the front face of the block.

626. The locking recess is cut in the surface of the guide cylinder. The depth of this locking recess gradually increases from rear to front, beginning at zero at the rear and terminating at the front end in a well called the locking recess. When the block is withdrawn the inner end of the latch bolt drops into the locking recess and locks the block positively to the block carrier. The gear segment is attached to the rear end of the breechblock by a spline and two screws. It consists, essentially, of a segment of a bevel gear and a short rack, which mesh with a pinion pivoted on the block carrier and actuated by the lever. Part of the periphery of the pinion is cut into a bevel gear and another part into a pinion, meshing with the corresponding parts of the gear segment. The bevel-gear parts rotate the block and the rack-and-pinion parts translate it. These motions are successive; the termination of the motion of rotation in opening the breech brings the rack and pinion into the proper position to withdraw the block, and the termination of the motion of translation in closing the breech brings the bevel-gear segments into mesh to rotate it.

627. *Firing mechanism.*—This mechanism is intended for use with a combination electric and friction primer. It consists of the following principal parts: Slide, slide housing, ejector, firing leaf, contact clip, firing cable, circuit breaker, and safety bar. The housing is attached to the rear end of the spindle by means of an interrupted-screw thread and is secured in place by a spline screw. The slide has a vertical movement in guides which project from the rear portion of the housing, and its movement is limited by the slide stop, which has a horizontal movement in a slot cut in the housing, its inner end projecting into a groove in the side of the slide. The slide stop is pressed inward by a helical spring. The firing leaf is pivoted

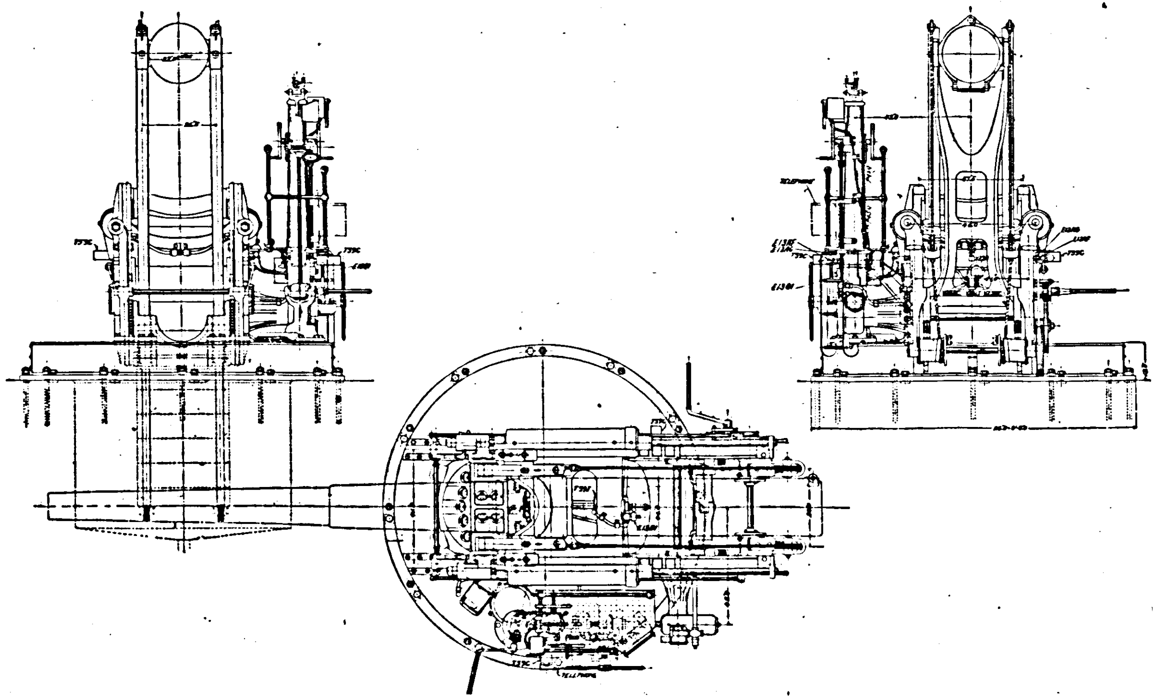
at its upper end to the slide, against which it lies flat when in its normal position.

628. A notch is cut through both the slide and the leaf, so that when in its lowered position the slide supports the head of the primer against the pressure of the powder gases, while allowing the primer wire to extend through the notch. When the leaf is swung to the rear, its rear face catches the button at the end of the primer wire and explodes the primer. The contact clip makes electrical connection with the primer by bearing against the button on end of primer wire when the slide is in its lowered position. The contact clip is held in position in the firing leaf by the contact-clip nut and is insulated from the leaf by the contact-clip insulation. One end of the firing cable is attached to the contact slip, the other end to the circuit-breaker contact piece by the firing cable terminals and the contact-clip plugs. The circuit-breaker contact piece is secured to the outside of the gear segment by two screws and insulated therefrom. When the block is rotated in closing, the circuit-breaker contact piece comes into contact with the circuit-breaker contact pin, making electrical connection with one of the firing leads.

629. The circuit-breaker contact pin and spring are inclosed in a housing which is attached to the block carrier by two screws and insulated therefrom. The pin is held against the contact piece by the pressure of its spring. The circuit-breaker contact pin forms the end of the firing lead and is held in the circuit-breaker housing by the circuit-breaker housing plug. The firing lead is held in place by the cable clamp screwed to the block carrier. The ejector consists of a horizontal and a vertical branch with two trunnions near the angle. It is supported in the housing by these trunnions, and in its normal position the lower branch, which is in the form of a fork, hangs vertically over the mouth of the primer seat, engaging the rim of the primer on two sides. The horizontal branch projects to the rear into a recess cut in the front face of the slide. The lower end of this recess is a cam surface. When the slide is raised, this cam surface forces the horizontal branch upward, ejecting the primer. When the slide is lowered, the ejector drops into position against the mouth of the primer seat.

630. The safety bar is a lever pivoted in the slide housing and actuated by a stud on the gear segment working in a slot cut through the outer end of the safety bar. At the beginning of rotation of the block in opening the breech the inner end of the safety bar rotates inward, entering a slot in the right side of the firing leaf, thus preventing any movement of the firing leaf except when the breech is fully closed.

PLATE 284.



FRONT, REAR, AND PLAN VIEWS OF THE 6-INCH DISAPPEARING CARRIAGE, MOD

645. *Elevating mechanism.*—The elevating mechanism comprises a double screw and is the first of this type that has so far been encountered. An elevating bracket, bolted to the rear of the pivot yoke, provides bronze bushed beds for the trunnions of the elevating nut. Dovetailed cap squares are bolted to the trunnion beds. The gear case and lower bearing are bolted to the right side of the bracket. The upper bearing is bolted to its seat on the right cheek of the pivot yoke. By means of the elevating handwheel, its shaft, the handwheel shaft gears, the intermediate elevating shaft, the intermediate elevating gears, the elevating-nut shaft, the elevating pinion, the elevating gear, the elevating nut, and the outer and inner elevating screws motion is communicated to the cradle. The upper end of the inner elevating screw forms an eye which is hinged between two flanges on the cradle beneath the recoil cylinder by the elevating pin.

646. To reduce the power required to elevate or depress the gun to a minimum, the cradle trunnions are so located that the center of gravity of the gun (with the projectile and charge in place), cradle, and all parts attached to them lies on the axis of the trunnions; for the same reason the center of gravity of all parts moving in azimuth lies approximately on the vertical axis of rotation of the pivot yoke.

647. *Traversing mechanism.*—The pivot yokes rests and is traversed upon a circle of 36 forged-steel conical rollers held in proper relative positions by a bronze roller cage. The upper roller path, of forged steel, fits into the shoulder of the pivot yoke and is held in position on the rollers by a flange on its outer circumference. The lower roller path is machined on the shoulder on the pedestal. The traversing mechanism consists of a traversing gear bracket, with cover plate and oil pan, a handwheel bracket, a handwheel and shaft, the upper traversing gears, the intermediate shaft, the lower traversing gears, the worm shaft, the worm, and two ball-thrust bearings. The bracket is bolted to its seat on the pivot yoke. A bronze bearing for the worm shaft is screwed into its forward end, with a notched head permitting of its being latched in adjustment by the worm-bearing latch, which is secured in the proper notch by a split pin. The other end of the worm shaft is supported in a bronze bushed bearing. The worm is keyed to the worm shaft, and ball-thrust bearings on the worm shaft at each end of the worm take up the thrust in traversing. The traversing worm wheel is seated on the outside of the annular vertical flange on the base of the pedestal, with a diametral clearance of 0.005 inch, and is retained in position by a shoulder on the pedestal and the brass azimuth circle secured by 16 countersunk screws to the top of the flange. Beneath the teeth on the worm wheel is a seat for the friction band, made in halves united and attached to a boss on the rear of the pedestal by a stud bolt, thereby preventing rotation of the band with the pivot

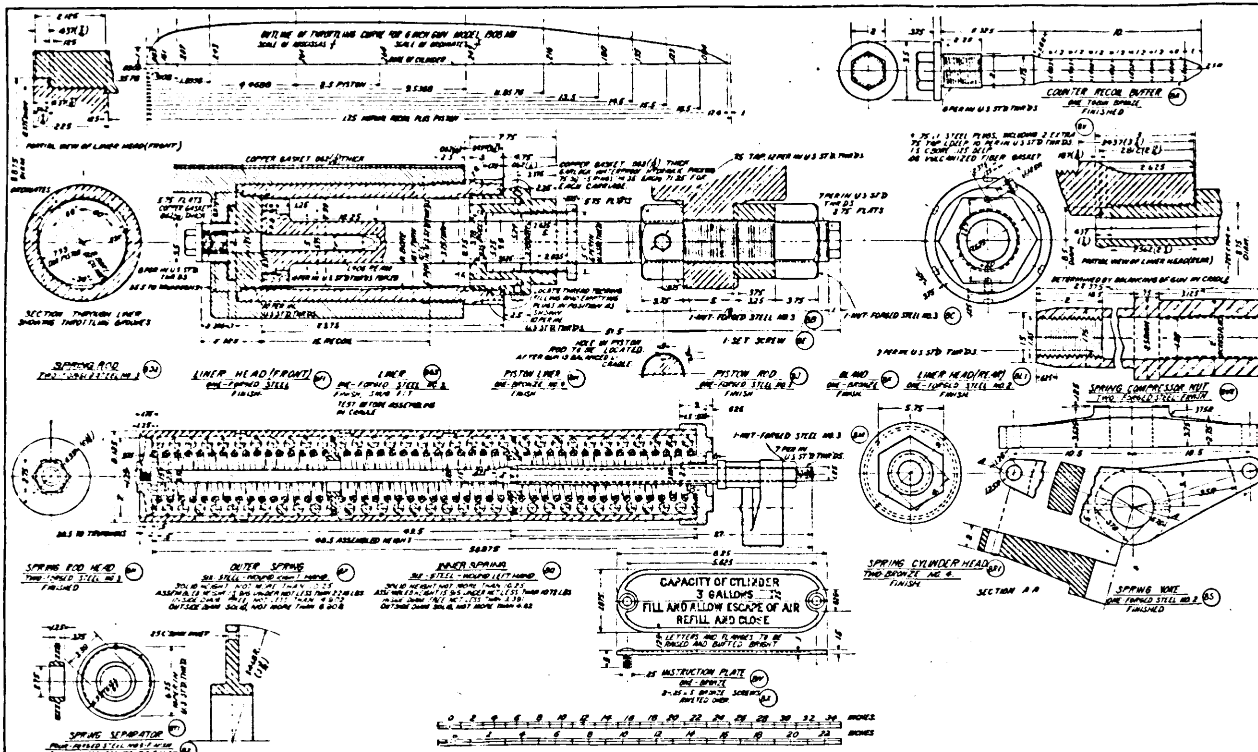
yoke. The other ends of the halves of the band are joined by a bolt having a helical spring interposed between them and the nut. These nuts should be tightened to produce only sufficient friction between the band and the worm wheel to enable the gun to be traversed without slipping and yet permit slipping in case undue strain is brought on the teeth of the worm wheel. The spring serves to regulate and keep unifrom during rotation the pressure of the band on the worm wheel.

648. The handwheel bracket is bolted to the top of the standard forming the rear part of the traversing gear bracket. The intermediate shaft is incased in this standard. Bronze bushed bearings are provided in the standard and in the handwheel bracket for the intermediate and handwheel shafts. The handwheel bracket provides a slotted seat for the firing pistol (or firing magneto) and a drilled boss to which the shoulder rest is bolted.

649. *Loading mechanism.*—The projectiles are wheeled to the breech of the gun on shot trucks. Four are furnished with each carriage. The frame of the truck is built up mainly of steel angles riveted. The shot supports are two steel angles running the length of the truck, and curved up at their ends to provide stops for the projectiles and attachment of the handle. The truck is supported by four wheels, two in the center of large diameter and on the outside of the truck, and one small one at each end, all of which are rubber tired. It is handled by one man at the handle. The projectiles are placed across the truck on the shot supports, which are of sufficient length to accommodate six projectiles.

650. *Top carriage.*—The top carriage, Plate 285, comprises a cradle carrying the single recoil and double recuperator cylinders and in turn is mounted by its trunnions in the supports of the pivot yoke. The pivot yoke of cast steel has a cored cylindrical stem from which rise two vertical cheeks. In the latter are trunnion beds for the cradle, which are fitted with dovetailed cap squares bolted to the cheeks. The beds are bronze lined. Finished seats are formed on the outer faces of the cheeks, to which the shield supports are bolted. On the left front of the yoke, near the bottom, is a boss having a finished seat to which the traversing gear bracket is bolted. A seat for the sight bracket is provided on the left cheek just forward of the trunnion bed. A seat for the upper bearing and disk bracket is finished on the right cheek of the yoke in rear of the trunnion bed. A boss formed on the rear of the cylindrical portion of the yoke below the cheeks provides a seat for the elevating-gear bracket. The two platforms are attached by bolts to seats on the right and left of the yoke. The upper and lower sleeves, roller path, and roller bearings are oiled through oil tubes, which are closed by

PLATE 287.



SPRING RECUPERATOR AND HYDRAULIC BRAKE OF THE 6-INCH BARBETTE CARRIAGE, MODEL OF 1910.

yet enable slipping to occur before any injurious strain is brought on the elevating worm wheel and worm. Nine hundred pounds applied at the muzzle should slip the friction.

658. *Traversing mechanism.*—The traversing mechanism consists of the traversing worm wheel, traversing worm shaft and worm, two pairs of bevel gears, two traversing shafts, and traversing handwheels. The traversing worm wheel is seated with a diametrical clearance of 0.01 inch on the exterior of the cylindrical top of the pedestal, and is retained in position by a shoulder on the pedestal and a steel ring secured by 12 screws to the top of the pedestal. Two oil holes are provided in this ring and through the top of the pedestal for oiling the bearing of the traversing worm wheel. The traversing worm wheel is protected from dirt and damage by the traversing-gear case, made in two parts to permit assembling, and bolted to the four bosses on the pivot yoke. In the rear part of the case are the bearings and seat for the traversing worm shaft and worm. Beneath the teeth on the worm wheel is a seat for the friction band, made in halves and united by and attached to the boss on the front of the pedestal by a stud bolt, thereby preventing rotation of the band with the pivot yoke.

659. The other ends of the halves of the band are joined by a bolt having a helical spring interposed between them and the nuts. These nuts should be tightened to produce only sufficient friction between the band and worm wheel to enable the gun to be traversed without slipping and yet permit slipping in case undue strain is brought on the teeth of the worm wheel. The spring serves to regulate and keep uniform during rotation the pressure of the band on the worm wheel. The traversing worm shaft is assembled with its worm in the traversing-gear case in rear of the pedestal; its ends are supported in bearings attached to the platform brackets, and carry bevel gears into which the gears on the front ends of the traversing shafts mesh. Two ball thrust bearings incased in collars bear on either side of the traversing worm and transmit the thrust to the worm casing. Concave and convex washers are provided between worm casing and ball bearing to equalize thrust on the ball bearings. Between the ball-bearing thrust collar and the traversing shaft are a split-collar and thrust-collar nut, the latter also split. Any excessive end play in worm may be taken up by the thrust-collar nuts. The traversing shaft on the left side is supported by two bearings attached to the platform and elevating brackets, and the one on the right side of two bearings attached to the platform bracket and shoulder rest. On the rear end of each shaft is a handwheel.

660. *Loading mechanism.*—See paragraph 649.

661. *Top carriage.*—The top carriage comprises the cradle and pivot yoke. The cradle, of cast steel, is bored out and bushed with

bronze to receive the gun. Oil grooves formed in the bushings and connected with the seven oil holes in the cradle insure proper lubrication of the bearing surfaces. Near the front end are trunnions for supporting the cradle and gun in the pivot yoke and on which the cradle and gun rotate when the latter is elevated or depressed. The holes in the trunnions are closed with screw plugs. In front of the recoil cylinder is a stop which limits the elevation to 16° by striking the pivot yoke.

662. The pivot yoke, of cast steel, has a cord conical stem from which rise two vertical cheeks. In the latter are trunnion beds for the cradle which are fitted with dovetailed cap squares bolted to the cheeks. The beds are bronze lined. Finished recesses are formed in the outer faces of the cheeks into which the shield supports are fitted. These supports are also bolted to the cheeks of the pivot yoke. Annular projections are formed on the pivot yoke to prevent the entry of water in the bearings of the pivot yoke in the pedestal, and the ends of the cored hole in the stem are closed with plugs. On the underside of the checks are four bosses to which the traversing-gear case is bolted; the platform brackets are attached by bolts to their rear faces. Two oil holes are provided in the pivot yoke for oiling its upper bearing in the pedestal, and an oil pipe leading from a third hole to the thrust bearing near the lower end of the pivot yoke enables that bearing to be slushed with oil.

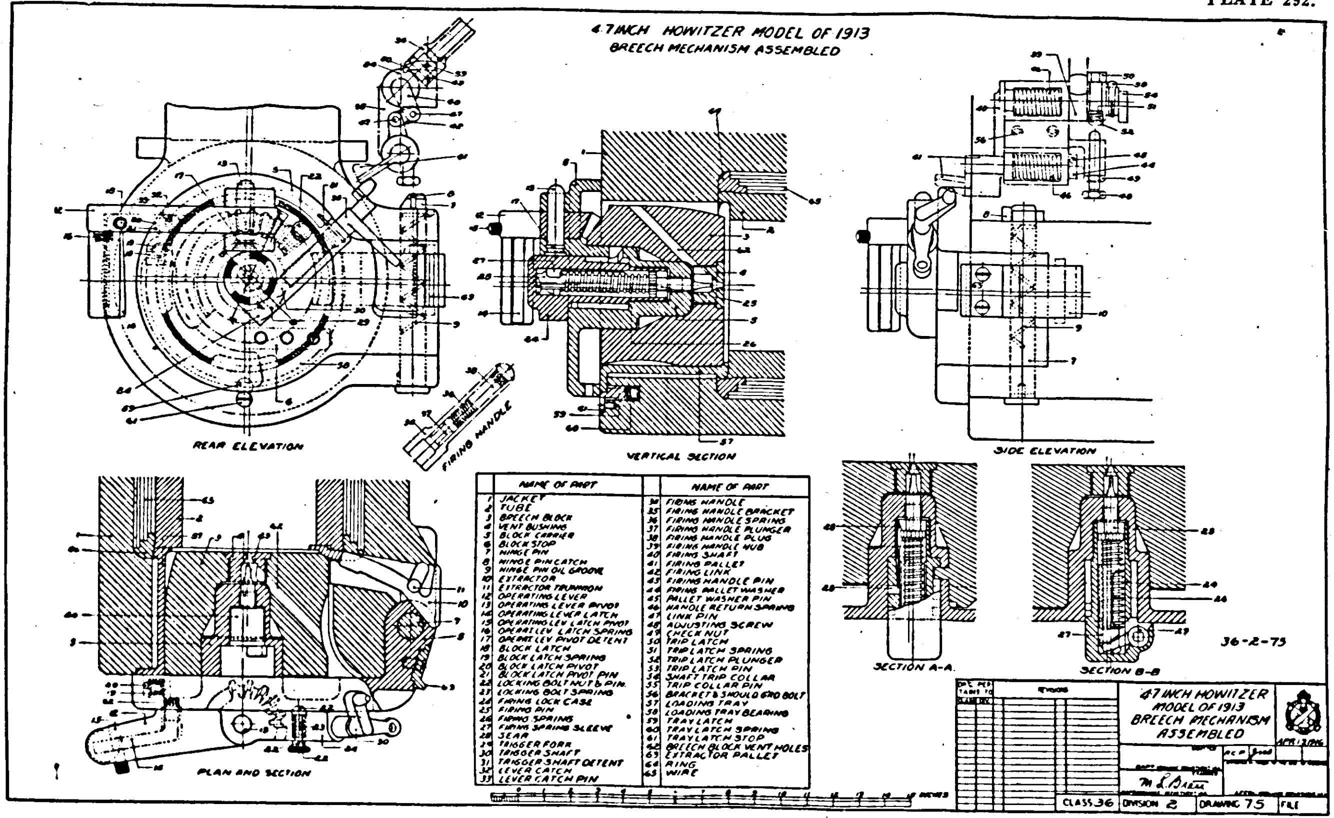
663. *Pedestal.*—The pedestal is made of cast steel. The general form is that of the frustum of a cone united at its top to a cylindrical section and at its bottom to a base, in the flange of which are drilled holes for the 16 foundation bolts and 4 leveling screws. Four manholes covered with plates are provided for cleaning the interior; the joints of the covers are made watertight by means of Garlock's gasket packing. The exterior of the cylindrical part is finished and forms a seat for the traversing worm wheel; beneath this seat on the front of the pedestal is a boss to which the friction band is secured.

664. An annular boss is cast in the bottom of the pedestal. This boss is bushed with bronze and forms a bearing for the lower end of the pivot yoke. The upper cylindrical part of the pedestal is also bushed with bronze. These two bearings serve to keep the pivot yoke in a vertical position. The weight of the revolving parts is supported by a plain roller thrust bearing inserted between a shoulder near the lower end of the pivot yoke and the annular boss on the pedestal base.

34. 6-INCH R. F. ARMSTRONG GUN ON 6-INCH ARMSTRONG BARBETTE CARRIAGE.

665. The gun, carriage, and breech mechanism are illustrated on Plates 289 and 290. It will be observed that this gun and carriage

PLATE 292.



	NAME OF PART		NAME OF PART
1	JACKET	34	FIRING HANDLE
2	TUBE	35	FIRING HANDLE BRACKET
3	BREECH BLOCK	36	FIRING HANDLE SPRING
4	VENT BUSHING	37	FIRING HANDLE PLUNGER
5	BLOCK CARRIER	38	FIRING HANDLE PLUG
6	BLOCK STOP	39	FIRING HANDLE HUB
7	HINGE PIN	40	FIRING SHAFT
8	HINGE PIN CATCH	41	FIRING PALLET
9	HINGE PIN OIL GROOVE	42	FIRING LINK
10	EXTRACTOR	43	FIRING HANDLE PIN
11	EXTRACTOR TRUNNION	44	FIRING PALLET WASHER
12	OPERATING LEVER	45	PALLET WASHER PIN
13	OPERATING LEVER PIVOT	46	HANDLE RETURN SPRING
14	OPERATING LEVER LATCH	47	LINK PIN
15	OPERATING LEV LATCH PIVOT	48	ADJUSTING SCREW
16	OPERAT LEV LATCH SPRING	49	CHECK NUT
17	OPERAT LEV PIVOT DETENT	50	TRIP LATCH
18	BLOCK LATCH	51	TRIP LATCH SPRING
19	BLOCK LATCH SPRING	52	TRIP LATCH PLUNGER
20	BLOCK LATCH PIVOT	53	TRIP LATCH PIN
21	BLOCK LATCH PIVOT PIN	54	SHAFT TRIP COLLAR
22	LOCKING BOLT NUT & PIN.	55	TRIP COLLAR PIN
23	LOCKING BOLT SPRING	56	BRACKET & SHOULD GRD BOLT
24	FIRING LOCK CASE	57	LOADING TRAY
25	FIRING PIN	58	LOADING TRAY BEARING
26	FIRING SPRING	59	TRAY LATCH
27	FIRING SPRING SLEEVE	60	TRAY LATCH SPRING
28	SEAR	61	TRAY LATCH STOP
29	TRIGGER FORK	62	BREECH BLOCK VENT HOLES
30	TRIGGER SHAFT	63	EXTRACTOR PALLET
31	TRIGGER SHAFT DETENT	64	RING
32	LEVER CATCH	65	WIRE
33	LEVER CATCH PIN		

which is to the right and at a pitch increasing from one turn in 40 calibers to one turn in 20 calibers. As mentioned before, this same model of gun is used on the pedestal mounting, model 1915.

679. *Breech mechanism.*—This breech mechanism, Plate 292, is of the Stockett type and is described under paragraph 624.

680. *Firing mechanism C.*—This is the first firing mechanism of this type that we have encountered. It will be observed on Plate 292 that the firing mechanism is incorporated in the breechblock and that the striker fires a primer which has been pressed into the base of the metal cartridge case. This cannon is served with fixed ammunition. The firing mechanism belongs to the type known as the continuous pull, percussion type—that is, no cocking of the firing pin is required other than a pull on the lanyard or trigger shaft. This arrangement permits repeating the blow from the firing pin in case of a misfire as often as desired, without the opening of the mechanism or recocking of the firing pin. It consists principally of the following parts: Firing case, firing pin, firing spring, firing-spring follower, sear, sear spring, and cocking lever.

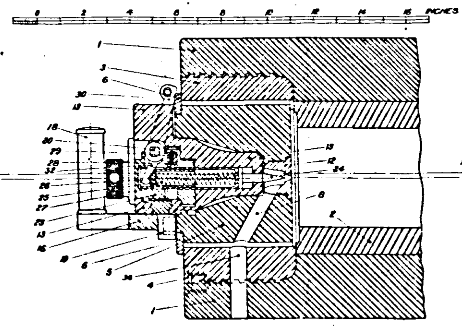
681. The firing case is designed to contain the complete firing gear, and, if necessary, the entire firing mechanism can be replaced in an instant. It contains all parts of the firing mechanism. It is provided with three lugs by which it is locked in place in the hub of the block carrier. Another lug which is forward of the other three engages the spiral groove in the breechblock, the four lugs locking the block and carrier together. The firing case is held from displacement by the trigger shaft. It can be removed from its seat, in the event of becoming tight, by inserting the end of the trigger shaft in the hole drilled in the knurled portion of the case and revolving it to the left. Through the bottom of the firing case near the center a hole is bored and slotted through which the sear and sear spring is passed to its seat on the opposite side of the firing case. To the rear of this seat is a rectangular slot cut through to the center and which forms a clearance pocket and seat for the cocking lever to engage.

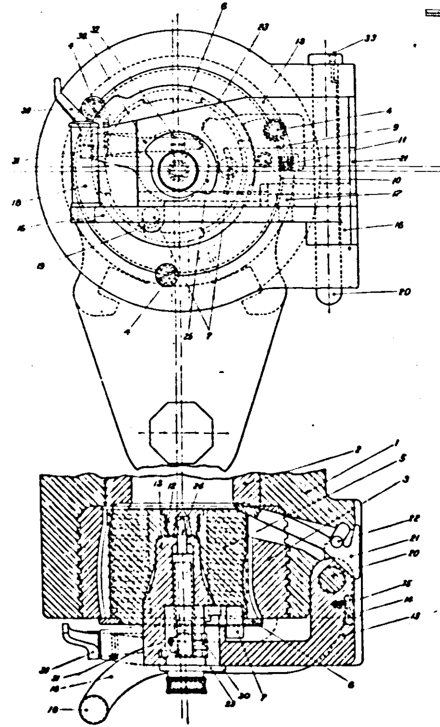
682. *Recoil mechanism.*—See recoil mechanism of 3-inch gun, model of 1903, on barbette carriage, model of 1903, paragraph 695.

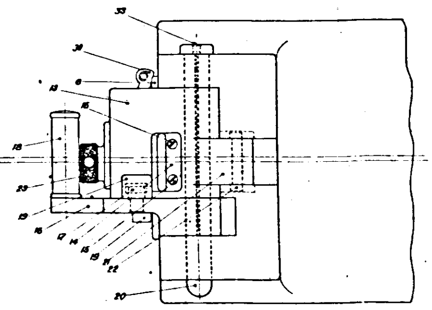
683. *Recuperator mechanism.*—The recuperator, Plate 294, comprises simply a single spring mounted about the recoil cylinder and in the spring cylinder. It bears against the rear of the spring cylinder and against the head of the recoil cylinder. As the gun recoils the spring is compressed by the head of the recoil cylinder and as soon as the gun is brought to rest it forces the head of the recoil cylinder forward, thereby pulling the gun back into battery.

684. *Elevating mechanism.*—It is possible to elevate the gun from minus 10 degrees, the loading angle, to plus 40 degrees by means of

3 INCH (15 PDR.) GUN, MODEL OF 1903
BREECH MECHANISM, ASSEMBLED.







1	JACKET	23	FIRING CASE
2	TUBE	24	FIRING PIN
3	BREECH BUSHING	25	FIRING SPRING
4	BREECH BUSHING SCREWS	26	FIRING SPRING FOLLOWER
5	BREECH BLOCK	27	FIRING SPRING FOLLOWER PIN
6	BREECH BLOCK FLANGE	28	SEAR
7	BREECH BLOCK OPERATING PINS	29	SEAR SPRING
8	BREECH BLOCK VENT HOLE	30	TRIGGER SHAFT
9	BLOCK LATCH	31	TRIGGER SHAFT DETENT
10	BLOCK LATCH PIVOT	32	COCKING LEVER
11	BLOCK LATCH SPRING	33	HANDY OILER FOR HINGE PIN
12	VENT BUSHING	34	VENT HOLE THROUGH BUSHING AND GUN
13	BLOCK CARRIER		
14	BLOCK CARRIER PALLET		
15	BLOCK CARRIER PALLET SCREWS		
16	OPERATING LEVER		
17	OPERATING LEVER PIN		
18	OPERATING LEVER HANDLE		
19	OPERATING BAR		
20	HINGE PIN		
21	EXTRACTOR		
22	EXTRACTOR TRUNNION		

26-6-13

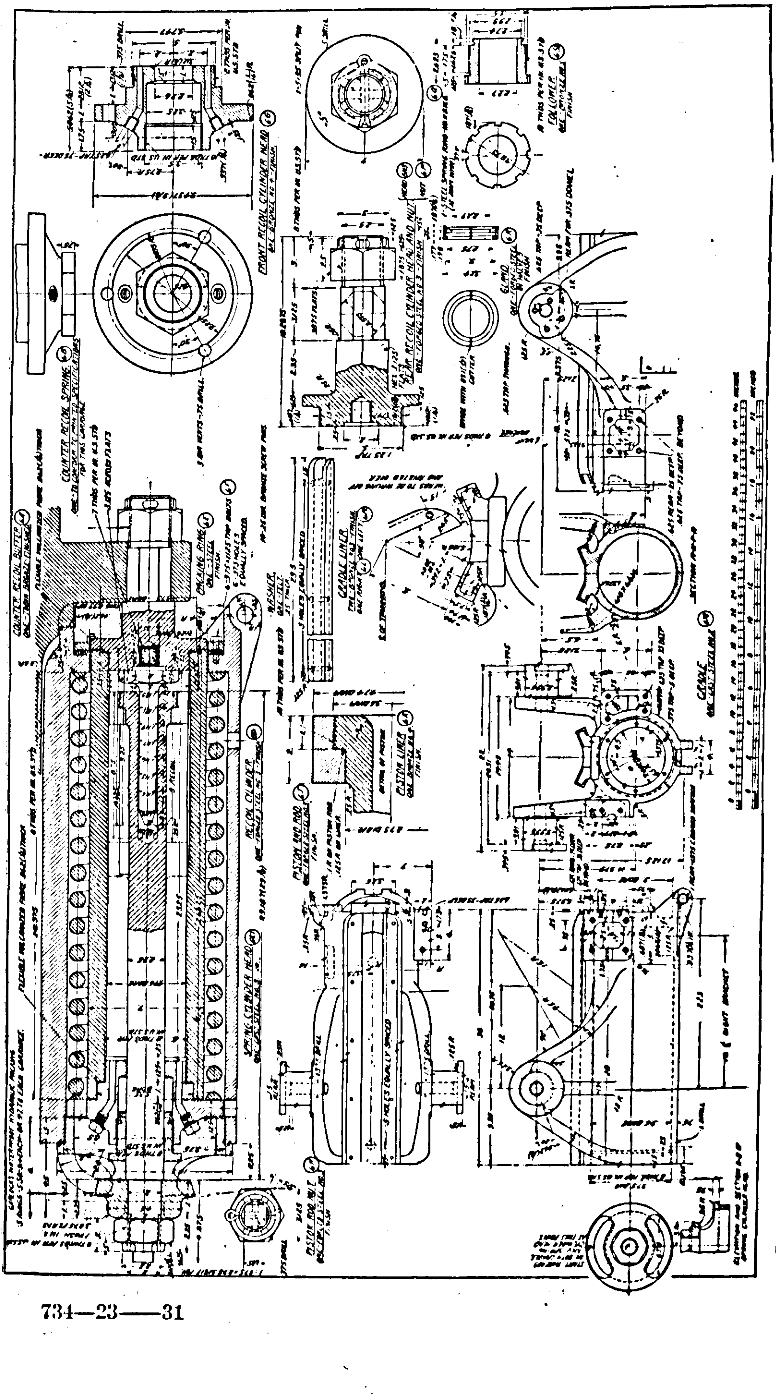
itself, it can not be said to embody any unique features. The rear of the recoil cylinder is attached to the recoil band and the cylinder recoils with it, while the piston and piston rod are attached to the head on the front end of the spring-cylinder and remain stationary. The counter-recoil buffer may be considered one with the recoil cylinder, in that it is screwed to the head—that is, attached to the recoil band. The front head of the recoil cylinder serves as a piston for the spring column and compresses the spring as the recoil cylinder moves to the rear.

696. *Recuperator mechanism.*—See paragraph 695.

697. *Elevating mechanism.*—The elevating mechanism consists of a handwheel actuating through suitable connecting shafts and bevel gears, and a double screw with right-hand outer threads and left-hand inner threads. The outer elevating screw is of forged steel and turns in a bronze elevating nut and cap. It receives its rotary motion from the elevating bevel gear by means of two keys sliding in longitudinal grooves cut in the outside of the screw. The inner screw has a left-hand thread and has its upper end attached to the lug on the bottom of the rear end of the spring cylinder. The elevating-screw nut is pivoted on trunnions so as to allow the necessary rotation, corresponding to different angles of elevation. The elevating-screw nut is provided with an elevating-screw nut cap bolted to it by four bolts. The elevating-screw cap has an oil hole and plug, and the elevating-screw nut has a hole fitted with a plug for draining. The elevating bevel gear is of bronze and the pinion is of forged steel. The pinion is keyed onto the elevating intermediate shaft, which receives its motion from the handwheel by the elevating handwheel shaft and a set of elevating handwheel shaft gears inclosed in gear covers. The elevating handwheel shaft has a bearing near the handwheel in a bracket secured to the shoulder rest. The elevating-gear bracket cap has a bearing for the lower end of the elevating handwheel shaft and serves as a cap for the trunnions of the elevating-screw nut.

698. *Traversing mechanism.*—The traversing mechanism consists of the traversing worm wheel, traversing worm shaft and worm, one pair of bevel gears, one traversing shaft, and one traversing handwheel. The traversing worm wheel is seated on the exterior cylindrical top of the pedestal, and is retained in position by the friction band, a shoulder on the pivot yoke, and a shoulder on the pedestal. A pair of bevel gears, in a cast-iron bevel-gear cover, serve to transmit the motion of the traversing handwheel and traversing handwheel shaft to the end of the traversing worm shaft. The traversing handwheel shaft is supported in its proper position by two brackets containing suitable bearings. One bracket is bolted to the elevating-gear bracket and the other is bolted to the shoulder rest.

PLATE 30d.



CRADLE DETAILS, RECOIL AND COUNTER-RECOIL ASSEMBLY OF 3 INCH (15 PDR.) BARBETTE CARRIAGE, MODEL OF 1903.

703. The exterior of the cylindrical part is finished and forms a seat for the traversing worm wheel. Beneath this seat on the front of the pedestal is a boss to which the friction band is secured by a stud bolt. An annular boss is cast in the bottom of the pedestal. This boss is bushed with bronze and forms a bearing for the lower end of the pivot yoke. The upper interior cylindrical part of the pedestal is also bushed with a bronze bearing. These two bearings serve to keep the pivot yoke in a vertical position. The weight of the revolving parts is supported by a ball-thrust bearing inserted between the end of the pivot yoke and the bottom of the cylindrical recess formed by the annular boss at the bottom of the base of the pedestal.

37. 15-POUNDER GUN, MODEL BETHLEHEM L-50-B, ON BARBETTE CARRIAGE, MODEL 1902.

704. This gun and carriage are illustrated on Plates 301–304. Both the gun and carriage differ from the model just described.

705. *Cannon.*—The gun, Plate 301, is of steel, and consists of a tube, a jacket, a breech bushing, and the breech mechanism. The tube is enveloped for a distance of 90 inches from its breech end by the jacket. The jacket is assembled on the tube from the muzzle end, a shoulder on it abutting against a corresponding one on the tube 26.5 inches from the breech end. The jacket projects to the rear sufficiently to form a recess into which a breech bushing is screwed, forming the breech recess. The jacket has a lug on the right-hand side for the seats of the hinge and extractor pins and rotating lever; also recess cut through the same side for the extractor. Underneath, and in a plane of 90 degrees from the hinge-pin lug, is a lug to which the piston rod is secured.

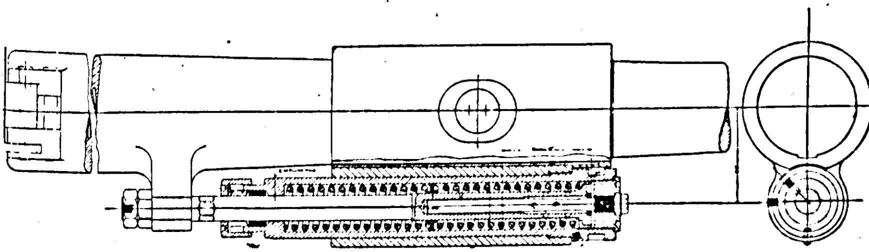
706. The bore of the gun is composed of the seat for the cartridge case and rotating band and the main bore. The twist of the rifling increases from one turn in 50 calibers at the breech end to one turn in 25 calibers at a point 9.13 inches from the muzzle, retaining this twist to the muzzle. The breech recess contains four-slotted and four-threaded sectors so placed as to receive the corresponding sectors of the breechblock.

707. *Breech mechanism.*—The breech mechanism, Plate 302, consists principally of the block, carrier plate, latch, carrier hub, operating lever and link, extractor, and firing mechanism. The block is cylindrical in form, 4.355 inches long and 5.7 inches in exterior diameter, except at the rear end, where there is a collar with an exterior diameter of 6.7 inches. The part in front of the collar consists of four-threaded and four-slotted sectors of about equal area. The metal in each of these sectors is cut away sufficiently to allow the

block to swing clear of its recess. The thread of the threaded sectors is trapezoidal in form, rounded at the top and bottom. A boss on the rear face of the block forms a seat for the link pivot. A stud screwed into the rear face of the block, carrying an insulated copper plug, forms half of the circuit breaker for the electric firing mechanism.

708. The block is bored axially to a diameter of 2.55 inches and a depth of 2.38 inches from the rear face. This bore is continued through the block on a diameter of 1.69 inches, the front end being counterbored to a diameter of 2.1 inches. The bore at the front end is threaded and a plug having an axial hole for the firing pin is screwed into it. A spline screw prevents this plug from turning. The large diameter bore at the rear end is also threaded, the thread being rectangular in form and having the same pitch as that on the exterior of the breechblock. A slot on the left-hand side of this bore

PLATE 303.



COMBINATION RECOIL AND RECUPERATOR MECHANISM OF THE BETHLEHEM CARRIAGE.

allows for movement of the trigger when the block is in its closed position.

709. *Firing mechanism.*—The firing mechanism is of the type known as continuous-pull percussion combined with electric. It consists principally of the following parts: Firing pin with insulation, firing-pin sleeve, firing-pin guide and firing-pin shoulder, firing-pin spring, trigger and spring and trigger pin, cocking link and stud with spring, cocking-stud block.

710. If we assume that the gun is loaded and the block closed the conditions for electric firing are as follows: The firing-pin guide is pressed forward by the firing-pin spring against the front firing-pin shoulder. The firing pin is thus pressed forward against the primer. The connection is now complete for electric firing. Unless held back by the primer the projection of the firing pin in this position is about 0.05 of an inch. For percussion firing the trigger is pulled to the rear until the cocking stud is released from the firing-pin sleeve. In this movement the firing pin is pulled to the rear about 0.8 of an inch. When released the spring drives it forward until the firing-pin guide

strikes the breechblock plug. The inertia of the firing pin and sleeve then carries them 0.1 of an inch farther forward. The total projection of the firing pin in percussion firing is 0.15 of an inch.

711. *Recoil mechanism.*—The recoil cylinder is made of forged steel. It is turned to an exterior diameter of 5.5 inches and bored to an interior diameter of 4.25 inches. At the forward end for a length of 4 inches its exterior diameter is 6.5 inches, and in the rear of this, for a length of 2 inches, it is threaded on an exterior diameter of 6 inches. This threaded part is screwed into the forward part of the recoil-cylinder sleeve in the cradle. The front end of the cylinder is closed by a steel cylinder head provided with a copper gasket, Plate 303. A bronze throttling rod extending into the bore of the piston rod is screwed into the cylinder head. The rear end of the cylinder is provided with a stuffing box for the piston rod, consisting of a follower, a gland, and three rings of Garlock's hydraulic packing 0.5 inch square. The threads for the follower are on the exterior of the cylinder, and therefore do not interfere with the removal or replacement of the packing.

712. The piston rod and piston are of forged steel, in one piece. A bronze sleeve screwed over the piston has a clearance of 0.005 inch in the cylinder. The diameter of the main part of the piston rod is 2.24 inches. The forward part is 2.45 inches in exterior diameter and is bored out to a diameter of 1.5 inches for a depth of 6.3 inches and to a diameter of 1.25 inches for 8.8 inches farther. A throttling ring of steel, having a hole 1.25 inches in diameter, is screwed into the end of the piston. Eight radial holes (0.375 inch) are provided through the walls of the piston symmetrically distributed from 2.1 to 5.2 inches from the end of the piston.

713. *Recuperator mechanism.*—Counterrecoil is effected by a coiled spring in two sections with a separator between them. This spring bears against the piston in front and against a shoulder of the recoil cylinder in rear. In recoil, throttling of the oil in the cylinder is effected by the passage of the oil through these radial holes and through the clearance between the throttling rod and the throttling ring, which clearance is made by varying diameters of the rod such as to maintain a constant pressure in the coil in the cylinder during recoil.

714. In counterrecoil the oil caught in the hollow piston rod is forced by the throttling rod through the eight radial holes already referred to, through the clearance between the throttling rod and the walls of the hollow piston rod, and through a hole 0.22 inch in diameter placed 3.35 inches from the bottom of the bore in the piston rod, and thus the shock of counterrecoil is softened. The end of the piston rod passes through a lug on the gun and is secured by a nut and lock nut.

720. The pivot yoke, of cast steel, rests on the ball-bearing ring in the pedestal and turns in the bronze bushings of the pedestal with a diametrical clearance of 0.003 inch. It carries the traversing and elevating apparatus of the carriage and has bronze-bushed trunnion beds with cap squares, in which rest the trunnions of the cradle. The front faces of both halves of the pivot yoke are machined and drilled for bolts for the purpose of receiving the shield supports.

721. *Pedestal.*—The pedestal, of cast steel, Plate 304, is the foundation piece of the carriage. It is bolted to the platform by ten 1.375-inch bolts through holes in a flange around the base. The pedestal is bored vertically to a depth of 15.75 inches from the top and bronze bushed to receive the pivot yoke, which, with the parts supported by it, rests upon a ring of ball bearings placed upon the pivot-yoke nut, which is screwed into the bottom of the bore of the pedestal. The entire weight of the gun and top part of the carriage, therefore, rests upon this ring of ball bearings, and thus friction in traversing is reduced to a minimum. The bushings for the pivot yoke are forced to their seats in the pedestal and form two supports against the thrust of firing. The upper bushing is 8.5 inches in interior diameter and 5 inches long, and is prevented from turning in the pedestal by three headless steel screws. The lower bushing is 5.75 inches in interior diameter and 3.375 inches long on the bearing part. It is prevented from turning by an oil tube screwed into it from the rear of the pedestal. Both bushings are provided with oil holes and grooves for lubrication.

722. The top of the pedestal is turned on the outside to a diameter of 14.495 inches to a shoulder 3 inches from the top. A bronze training worm wheel is placed over this part with a diametral clearance of 0.002 inch. A steel securing ring screwed to the pedestal, and projecting over a shoulder on the training worm wheel, prevents the latter from working up on the pedestal. At the front of the pedestal is placed a clamp consisting of a steel block, two guide studs, and a clamping screw and lever, by which the training worm wheel may be clamped to the pedestal. The objects of having the training worm wheel clamped by friction to the pedestal, instead of being rigidly attached to it, is to prevent undue strains on the traversing mechanism in case of rapid traversing and sudden stopping, in which case the friction arrangement allows slipping between the training worm wheel and the pedestal. Also, in case very rapid traversing is desired, the training worm wheel may be unclamped and the gun traversed by pushing on the breech or chase.

38. 3-INCH GUN, MODEL OF 1898, ON 15-POUNDER BARBETTE CARRIAGE, MODEL OF 1898 MI.

723. This gun and carriage are illustrated on Plates 305–309.

724. *Cannon.*—The gun, Plate 305, is of steel and consists of a tube, a jacket, a hoop, and the breech mechanism. The tube is enveloped for a distance of 84 inches from its breech end by the jacket and hoop. These latter two are locked together by a bronze sleeve that screws over 6 inches of the jacket and 5.5 inches of the hoop, and is locked in place by a key and screw. A shoulder on the jacket and another on the hoop abut against corresponding projections on the tube. The jacket projects to the rear sufficiently to form the breech recess, and has a lug on the right-hand side for the seat of the carrier-plate hinge lug and a recess cut through the same side for the extractor.

725. The bore of the gun is composed of the seat for the cartridge case and rotating band and the main bore. The twist of the rifling is right hand and increases from one turn in 50 calibers at the breech end to one turn in 25 calibers at a point 9.13 inches from the muzzle, retaining this twist to the muzzle. The breech recess contains three slotted and three threaded sectors so placed as to receive the corresponding sectors of the breechblock.

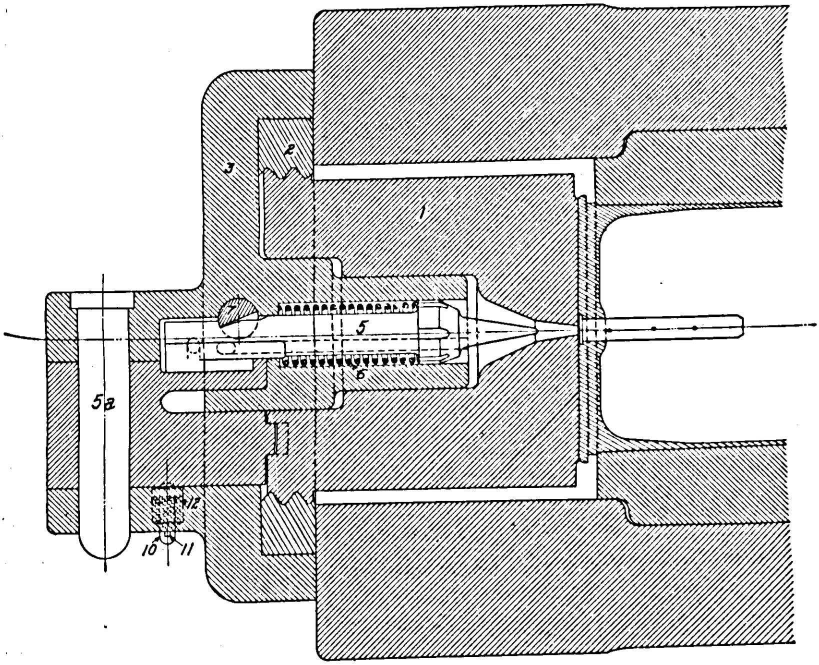
726. *Breech mechanism.*—The breech mechanism, Plate 306, consists of the block, carrier plate, carrier-plate ring and its screws, locking bolt and spring, operating lever and pin, lever plunger, spring and cotter pin, firing pin, firing-pin head and firing spring, sear, sear spring, extractor, hinge pin, sear latch, sear-latch pin, and safety catch, pin, and spring. The principal parts of the breechblock are three threaded sectors, three slotted sectors, the thread for the carrier-plate ring, the operating-lever slots, the recess for the firing pin, the rotating stop, and the seat for the locking bolt.

727. The thread is V shaped, rounded at top and bottom, and for about 0.75 inch in rear is continuous; the remainder is divided into six sectors, three threaded and three slotted. The continuous thread engages in that of the carrier-plate ring, and the threaded sectors engage those of the breech recess. The slotted sectors of the block and recess are cut away sufficiently to permit the block to enter the recess when swung about the hinge pin. The slot for the locking bolt is so placed that when the threads of the block are disengaged from those of the breech recess the locking bolt enters the slot, locking block, and carrier plate together. The operating lever is assembled between lugs on the rear face of the carrier plate and consists of the lever proper, the operating knob, the cocking cam, the handle, the seat for the pin, and the seat for the lever plunger. The lever passes through the carrier plate, the knob engaging in its seat

in the block and forcing it to rotate when the lever is turned about its pivot.

728. *Firing mechanism.*—The firing pin and spring are assembled in their seat in the carrier plate, the front end of the firing-pin head, when released, passing through an aperture in the front of the block, Plate 307. The pin has at the rear end a cocking lug and a notch for the engagement of the sear and in front the firing-pin head a shoulder for the spring. The spring is coiled around the pin and abuts against the shoulder in front, formed by the firing-pin head and the carrier plate in rear.

PLATE 307.



FIRING MECHANISM OF THE 3-INCH GUN, MODEL OF 1898.

729. The cocking cam engages a lug on the firing pin and is so shaped that in opening the breech the pin is retracted until caught and held by the sear. The lever projects to the front sufficiently to form a locking lug that, by the final motion in closing, is seated in a groove in the rear face of the block, thus preventing rotation of the block due to pressure of the powder gas. The final movement of the lever in closing and the first in opening is perpendicular to the face of the plate, the pivot hole being made elliptical for the purpose. The seat for the lever plunger is on the under side of the lever. The handle makes a right angle with the lever and is vertical.

730. *Recoil mechanism.*—The cylinder has a smaller diameter in front than in rear, the two portions being joined by an inclined

curved surface, Plate 308. On the interior the smaller part is cylindrical and is intended as a seat for the spring. The travel of the piston is limited to the larger part of the cylinder. Constant resistance is obtained by the passage of the liquid from one side of the piston to the other through varying orifices, depending upon the varying diameters of the interior. These diameters vary with the position of the piston in such a way as to obtain the desired resistance. The piston rod and head form one piece, the latter being of the same diameter as the front of the larger portion of the cylinder. Springs of a rectangular cross section abut against the piston head and the front end of the cylinder. There is a cylinder head in the rear and stuffing-box glands front and rear. The forward end of the piston rod is threaded for two nuts. A vent and filling hole are placed in the side of the cylinder.

731. *Recuperator mechanism.*—See Recoil mechanism above.

732. *Elevating mechanism.*—An elevation gear bracket of cast steel bolted to the right side of the pivot yoke contains the elevating gear. By means of the elevating handwheel, its shaft, a pair of miter gears, the elevating worm shaft and worm, the elevating worm wheel, and elevating pinion shaft and pinion, motion is communicated to the cradle by means of the elevating rack. The elevating worm wheel is assembled as a rim on a bronze disk between two other cast-iron disks which bear on its sides; the three disks are assembled on the elevating pinion shaft in such manner that the pressure between the wheel and the disks may be varied by means of the nut on the outer end of the shaft. This nut should only be tightened sufficiently to insure enough friction between the disks and worm wheel to enable the gun to be elevated and depressed and yet permit slipping to occur before any injurious strain is brought on the elevating worm wheel and worm.

733. *Traversing mechanism.*—The traversing mechanism consists of the traversing worm wheel, traversing worm and shaft, one pair of bevel gears, traversing handwheel shaft, and handwheel. The traversing worm wheel, with the friction band in its position, is seated on the exterior cylindrical top of the pivot socket and is retained thus by the worm-wheel support. This support is secured to the pivot socket by eight screws. The friction band is in turn bolted to the worm-wheel support.

734. A pair of bevel gears serve to transmit the motion of the traversing handwheel and traversing handwheel shaft to the end of the traversing worm shaft. The traversing handwheel shaft is supported in its proper position by bronze bushed bearings in the shoulder rest and in the traversing worm bracket. The latter is bolted to the front of the pivot yoke, and carries bronze bushed bearings for the traversing worm shaft. The bushing in the right end

is threaded, so as to be adjustable, and has a hexagonal head. A circular flange at the base of the head is notched and the bushing may be locked in any adjustment by means of a bushing latch, which is secured to the traversing worm bracket and fits into a notch on the flange. Two ball-thrust bearings on the ends of the traversing worm shaft take up the thrust when traversing the gun.

735. *Loading mechanism.*—The ammunition is fixed and of such a weight as to be handled entirely by hand.

736. *Top carriage.*—The top carriage comprises a cradle and pivot yoke. The cradle is of cast steel and consists of two cheeks connected by a loop and web. The loop is under the front part of the cheeks and the web is across the front of the loop; a hole for the piston rod is bored through the web. On the inside of each cheek there are two guides for the sleeve, and at the rear end of these trunnions, and directly under these two lugs. The rear end of the left cheek is drilled and tapped for the attachment of the left shoulder guard.

737. The pivot yoke is Y-shaped; the stem seats in the pivot socket and the arms furnish the trunnion beds. It rests on the pivot thrust bearing and has two bronze collars for the bearing surfaces. Lugs on the inside limit the elevation of the cradle. Four lugs, two on each arm, are bored out for the shield braces. The cap squares are secured by top bolts. The pivot thrust bearing is seated on the web of the pivot socket and supports the pivot yoke. It consists of a row of hardened-steel balls inclosed between two steel races and connected by a copper thimble.

738. *Base.*—The outer base is set into a concrete foundation, Plate 309, and forms the ultimate support for the entire mechanism. It is cylindrical in shape, with a circular hole in the bottom for the lower part of the inner base. The former has two flanges, of which the top one is for holding-down bolts, while the other, by means of connecting ribs, supports the first. The inner top edge is cut away, making a surface inclined 15 degrees to the axis of the base and serving to help center the inner base. The inner base is, roughly, a cylinder with a broad flange at the top. At the lower end is a turned surface that fits into the hole in the bottom of the outer base, and 3 inches from the edge of the flange and on the under side is a surface, inclined 15 degrees to the axis, that fits into the corresponding surface of the outer base. The interior is bored to receive the pivot socket. The two bases are held together by eight bolts. The pivot socket is cylindrical in shape and rests on the pivot-socket plate, which in turn rests on the concrete inside and inner base 32 inches from the top of the latter. Two bronze collars give a bearing surface on the exterior, while the interior of the upper part is bored out to give two bearing surfaces for the pivot yoke. A web near the center forms the support for the pivot thrust bearing.

PART IV.

MISCELLANEOUS DATA.

781. The following table of miscellaneous data on guns, carriages, and ammunition is only relatively complete. Additional information on many minor details of guns, carriages, and ammunition may be found, if desired, in the following official pamphlets:

1. None yet issued.
2. None yet issued.
3. None yet issued.
4. No. 1716.
5 and 5A. No. 1712.
6. No. 2001.
7. None issued.
8. None issued.
9. No. 1707.
10. No. 1705.
10A. No. 1709.
11. No. 1722.
12. No. 1702.
13. No. 1697.
14. No. 1696.
15. No. 1695.
16. No. 2020.
17. Nos. 2024 and 1987.
18. No. 2028.
19. No. 1694.
20. No. 1692.
21. No. 1693.
22. No. 1691.
23. No. 1700.
24. No. 1685.
25. No. 1690.
26. No. 1816.
27. No. 1711.
28. No. 1704.
29. No. 1703.
30. No. 1687.
31. No. 1686.
32. No. 1713.
33. No. 1688.
34. No. 1752.
35. No. 1783.
36. No. 1701.
37. No. 1766.
38. No. 1756.

Guns Nos. 1676 and 1665.
Mortars No. 1820.

CARRIAGE.

Description No.	Caliber.	Type.	Model.	Total weight.	Recoil mechanism. Type.	Number of cylinders.	Length.	Orifices.	Buffer.	Angle.
1	2	3	4	5	6	7	8	9	10	11
	Inches.			*Tons.*			*Inches.*			*Degrees.*
1	16	Barbette..	1919........	500	Hydraulic	4	40	Grooves.	Valve...	....
2	16	Disappearing.	1917........	835	...do......	2	89	Bars....	Plug....	1
3	16	Barbette..	1920........	....	...do......	4	....	Grooves.	...do.....	....
4	16	Disappearing.	1912........	637	...do......	2	89	Bars....	...do.....	1
5	14	...do......	1907, 07 MI..	318	...do......	1	73	...do....	...do.....	Vert.
5A	14	...do......	1907, 07 MI..	341	...do......	1	73	...do....	...do.....	Vert.
6	14	Turret....	1909........	....	...do......	1	48	Grooves.	...do.....	
7	14	Railway ..	E..........	218	...do......	1	60	...do....	...do.....	....
8	14	...do......	1920........	....	...do......	....	....	...do....	Valve...	....
9	12	Mortar....	1908........	63	...do......	2	24	...do....	...do.....	....
10	12	...do......	1896 MI, MII.	64	...do......	2	23	...do....	...do.....	....
10A	12	...do......	1896 MIII....	66	...do......	2	23	...do....	...do.....	....
11	12	Barbette..	1917........	151	...do......	1	30	...do....	...do.....	....
12	12	...do......	1892........	118	...do......	2	48	Bars....	...do.....	4.5
13	12	Disappearing.	1901........	251	...do......	2	67	...do....	...do.....	2
14	12	...do......	1897........	243	...do......	2	67	...do....	...do.....	2
15	12	...do......	1896........	186	...do......	2	67	...do....	...do.....	2
16	12	Railway..	1918........	161	...do......	2	35–14	Grooves.	...do.....	....
17	12	...do......	1918........	88	...do......	2	30	...do....	...do.....	....
18	12	...do......	1918........	97	...do......	2	37.5	...do....	...do.....	....
19	10	Disappearing.	1901........	167	...do......	2	57	Bars....	...do.....	1.3
20	10	...do......	1896........	122	...do......	2	57	...do....	...do.....	1.3
21	10	...do......	1896........	252	...do......	2	57	...do....	...do.....	1.3
22	10	...do......	1894 MI.....	131	...do......	2	54	...do....	...do.....	2
23	10	Barbette..	1893........	68	...do......	2	50	...do....	...do.....	4
24	8	...do......	1892........	42	...do......	2	40	...do....	...do.....	2
25	8	Disappearing.	1896........	104	...do......	2	42	...do....	...do.....	1.5

CARRIAGE—Continued.

Description No.	Caliber.	Type.	Model.	Total weight.	Recoil mechanism.					
					Type.	Number of cylinders.	Length.	Orifices.	Buffer.	Angle.
1	2	3	4	5	6	7	8	9	10	11
	Inches.			*Tons.*			*Inches.*			*Degrees.*
26	8	Railway..	1918.........	87	Hydraulic	1	48	Grooves.	Valve...	....
27	6	Disappearing.	1905 MII.....	56	...do.......	1	47	...do.....	...do.....	Vert.
28	6	...do.......	1905 MI.....	56	...do.......	1	40	...do.....	...do.....	Vert.
29	6	...do.......	1905.........	56	...do.......	1	40	...do.....	...do.....	Vert.
30	6	...do.......	1903.........	48	...do.......	2	40	Bars....	...do.....	1.3
31	6	...do.......	1898.........	33	...do.......	2	36	...do.....	...do.....	1
32	6	Barbette..	1910.........	....	...do.......	1	15	Grooves.	...do.....	....
33	6	...do.......	1900.........	20	...do.......	1	15	...do.....	...do.....	....
34	6	...do.......	Armstrong..	....	...do.......	1	....	Bars....	....	....
35	4.7	Railway..	1917.........	22	...do.......	1	12	Grooves.	...do.....	....
36	3	Barbette..	1903.........	3	...do.......	1	9	...do.....	...do.....	....
37	3	...do.......	1902.........	3	...do.......	1	....	...do.....	...do.....	....
38	3	...do.......	98 MI.......	3	...do.......	1	5	...do.....	...do.....	....

Description No.	Recuperator mechanism.						Chassis angle.[1]
	Type.	Cylinders or weight.	Initial air pressure.	Force holding gun in battery.	Spring columns per cylinder.	Sections per column.	
12	13	14	15	16	17	18	19
			Pounds per sq. in.	*Tons.*			
1	Pneumatic..........	2	1,770	208	....	....	10 degrees.
2	Weight..........	1	....	305	....	....	
3	Pneumatic..........	1	2,000	104	....	....	
4	Weight..........	1	....	222	....	....	Vertical.
5	.....do..........	1	....	87	....	....	Do.
5A	.....do..........	1	....	101	....	....	
6	Spring..........	4	....	30	3	7	
7	.....do..........	6	....	47.2	3	7	
8	Pneumatic..........	2	1,800	127.5	....	....	
9	Spring..........	2	....	17	3	4	
10	.....do..........	5	....	45	2	5	
10A	.....do..........	5	....	50.5	2	5	
11	.....do..........	4	....	50.0	3	4	4.5 degrees.
12	Gravity..........	....	....	....	....	....	2 degrees.
13	Weight..........	1	....	80	....	....	Do.
14	.....do..........	1	....	77	....	....	Do.
15	.....do..........	1	....	81	....	....	
16	Pneumatic..........	1	1,565	92	....	....	
17	.....do..........	1	1,370	21.4	....	....	
18	.....do..........	1	1,550	24.1	....	....	1.3 degrees.
19	Weight..........	1	....	55	....	....	Do.
20	.....do..........	1	....	40	....	....	Do.
21	.....do..........	1	....	40	....	....	
22	.....do..........	1	....	42	....	....	4 degrees.
23	Gravity..........	....	....	....	....	....	2 degrees.
24	.....do..........	....	....	....	....	....	1.5 degrees.
25	Weight..........	....	....	20	....	....	
26	Spring..........	4	....	20	3	4	1 degree.
27	Weight..........	1	....	15	....	....	
28	.....do..........	1	....	15	....	....	
29	.....do..........	1	....	15	....	....	1.3 degrees.
30	.....do..........	1	....	15	....	....	1 degree.
31	.....do..........	1	....	10	....	....	
32	Spring..........	2	....	3.3	2	3	
33	.....do..........	2	....	10	2	2	
34	.....do..........	2	....	....	....	....	
35	.....do..........	1	....	1.3	1	2	
36	.....do..........	1	....	....	1	1	
37	.....do..........	1	....	....	....	....	
38	.....do..........	1	....	.5	2	1	

[1] Where no angle appears in this column the recuperator is part of the tipping unit.

CARRIAGE—Continued.

Description No.	Elevating mechanism.							
	Type.	Power.		Speed.		Maximum.	Minimum.	Method of reducing friction in trunnions.
				Motor.	Hand.			
20	21	22		23	24	25	26	27
				Degrees per second.	*Degrees per turn.*	*Degrees.*	*Degrees.*	
1	Spur	Motor	Hand	7	1.06	+65	−7	Floating.
2	Screw	do	do	(1)	(1)	+30	−5	Bushing.
3	Spur	do	do	7.2	2.1	+65	−7	Floating.
4	Screw	Hand			(1)	+20	−5	Bushing.
5	do	do			(1)	+15	−5	Do.
5A	do	do			(1)	+15	−5	Do.
6	do	Motor	Hand	(1)	(1)	+15	−.09	Floating.
7	do	Hand			(1)	+30	0	Do.
8	Spur	Motor	Hand	6.23	2.1	+50	−7	Do.
9	Worm	Hand			.58	+65	0	Bushing.
10	Spur	do			12	+70	0	Do.
10A	do	do			12	+70	0	Do.
11	Screw	Motor	Hand	(1)	(1)	+35	0	Floating.
12	Worm	Hand			.57	+15	−7	Half bushing.
13	Screw	do			(1)	+10	−5	Bushing.
14	do	do			(1)	+10	−5	Do.
15	do	do			(1)	+10	−5	Do.
16	Worm	do			.58	+38	−5	Floating.
17	do	do			1.004	+65	−5	Bushing.
18	Spur	do			1.92	+60	−5	Do.
19	Screw	do			(1)	+12	−5	Do.
20	do	do			(1)	+12	−5	Do.
21	do	do			(1)	+12	−5	Do.
22	do	do			(1)	+12	−5	Do.
23	Worm	do			.69	+15	−7	Do.
24	do	do			.68	+18	−7	Do.
25	do	do			(1)	+12	−5	Do.
26	do	do			2.488	+42	0	Do.
27	Screw	do			(1)	+15	−5	Do.
28	do	do			(1)	+15	−5	Do.
29	do	do			(1)	+15	−5	Do.
30	do	do			(1)	+15	−5	Do.
31	Worm	do			(1)	+15	−5	Do.
32	Screw	do			(1)	+12	−3	Do.
33	Worm	do			.37	+15	−5	Do.
34	do	do				+16	−7	Do.
35	Screw	do			(1)	+49	−10	Do.
36	do	do			(1)	+16	−10	Do.
37	Worm	do			1.03	+15	−10	Do.
38	do	do			.88	+15	−5	Half bushing.

[1] Mounts with screw elevation and all disappearing carriages have variable speed with uniform motion of handwheel or crank.

CARRIAGE—Continued.

Description No.	Traversing parts.							
	Weight.	Type of bearing.	Mean diameter of roller path or ball race.		Traversing mechanism.			
					Motor full speed.	Slow motion hand-wheel.	Crank.	Extent of traverse
28	29	30	31		32	33	34	35
	Tons.		*Feet.*	*Inches.*	*Degrees per second.*	*Degrees per turn.*	*Degrees per turn.*	*Degrees.*
1	375	Roller	27	10	2	0.11	1.54	360
2	781	do	20	6	1.75	.11	1.18	360
3	160	do	20	6	2	.11	1.55	360
4	582	do	20	6	2	.127	1.34	170
5	282	do	16	1.5		.079	1.13	170
5A	282	do	16	1.5		.079	1.13	170
6	950	do	27	3.25	1.66			360
7	218	do	15	6		.076	.833	360
8	276	Ball	4	3.1	2	.1	1.19	360
9	49	Roller	13	2		2.37		[1] 360
10	50	do	12	3		2.4		360
10A	52	do	12	3		2.4		360
11	122	do	14	4.5		.072	2.54	360
12	101	do	9	6			1.46	360
13	227	do	15	10		.12	2.2	[1] 360
14	221	do	16	1.5		.12	2.3	[1] 360
15	169	do	16	1.5		.12	2.2	[1] 360
16	161	Plain				.033		10
17	88	Roller	7	6.6		.083		360
18	97	do	9	1.5		1.03		360
19	151	do	13	2.25	3		2.1	[1] 360
20	110	do	13	8			2.2	[1] 360
21	235	Roller	(2)	(2)			1.44	360
22	119	do	8	10			1.24	140
23	55	do	8	4			4.8	320
24	32	do	6	11			1.33	320
25	99	do	11	.08			3.4	[1] 360
26	87	do	6	11.12		1.04		360
27	52	do	9	3		.47	7	[1] 360
28	52	do	9	3		.47	7	[1] 360
29	52	do	9	3		.47	7	[1] 360
30	45	do	8	10		.55	8.2	[1] 360
31	30.5	do	8	2		.385	3.8	[1] 360
32		do	1	11.25		2.73		360
33	18	Plain				2.77		[1] 360
34		do						360
35	22	Ball		6		2.96		360
36	2.25	do		3.3		2.5		360
37	2.25	do						360
38		do		7.25		3.68		360

[1] Extent curtailed according to local conditions.
[2] Has inner and outer sets of rollers with 10 feet 4 inches and 24 feet 8 inches respective mean diameters of paths.

GUN.

Description No. (36)	Model. (37)	Type. (38)	Length. (39)	Diameter of breech. (40)	Diameter of muzzle. (41)	Weight. (42)	Length of powder chamber. (43)	Diameter of powder chamber. (44)	Capacity of powder chamber. (45)
			Calibers.	*Inches.*	*Inches.*	*Tons.*	*Inches.*	*Inches.*	*Cu. ins.*
1	1919 MII	Wire	50	62	27	163	121.26	22	40,000
2	1919	...do...	50	62	27	163	121.26	22	40,000
3	1920	...do...	25	....	....	....	....	....	....
4	1895	Built up	35	60	28	142	106.24	19	29,624
5	1907	Wire	34	44	22.8	49.9	68.91	16.8	15,000
5A	1910	...do...	40	44	23.8	61.9	88.41	16.8	19,323
6	1909	...do...	40	54	26	69.8	88.41	16.8	19,323
7	1919	...do...	40	44	23.8	61.9	88.41	16.8	19,323
8	1920	...do...	50	48	23.4	....	96	16.5	....
9	1908	...do...	10	27.6	20	8.1	21.13	12.5	2,674
10A	1890	Built up	10	38	21	13	21.13	12.5	2,674
10	1912	Wire	15	34	20	15.1	30.17	12.5	3,770
11	1895 MI	Built up	35	44.5	21	52	77.68	14.2	11,967
12	1888 MI, MII	...do...	34	46.2	20.2	52	77.68	14.2	11,967
13	1900–1895 [1]	...do...	35	46.2	20.2	52	77.68	14.2	11,967
14	1895	...do...	40	48.5	22	59.1	85	16.5	16,254
15	1888–1895 [1]	...do...	34	46.2	20.2	52	77.68	14.2	11,967
16	1895	...do...	35	46.2	20.2	52	77.68	14.2	11,967
17	1890	...do...	10	38	21	13	21.13	12.5	2,674
18	1919	...do...	20	32.9	20.7	20.2	33.345	13.4	4,790
19	1900–1895 [1]	...do...	40	40.4	18.5	34.3	70.396	13.75	9,283
20	1895–1888 [1]	...do...	35	37	17.5	29.8	65.48	11.8	7,017
21	1888–1895 [1]	...do...	34	38.5	16.8	30	65.49	11.8	7,017
22	1888	...do...	34	38.5	16.8	30	65.49	11.8	7,017
23	1888	...do...	34	38.5	16.8	30	65.49	11.8	7,017
24	1888	...do...	32	30	14	16	51	9.5	3,576
25	1888 MI, MII	...do...	32	30	14	16	51	9.5	3,576
26	1888	...do...	32	29.97	14	16	51	9.5	3,576
27	1908–1905 [1]	Wire	50	24	10.2	11	33.375	7	1,254
28	1903–1905–1908 [1]	Built up	50	24	9.8	10.3	43.405	8	2,090
29	1905	...do...	50	24	10.2	11	43.715	8	2,098
30	1900–1903–1905 [1]	...do...	50	24	9.8	10.2	43.425	8	2,114
31	1897 MI	...do...	50	....	....	....	33.375	7	1,254
32	1908 MII	Wire	50	24	10.2	10.2	33.375	7	1,254
33	....	....	....	....	....	....	....	....	....
34	Armstrong	....	40	....	....	....	22.6	6.708	734
35	1912	Built up	22	11.2	7	1	6.55	4.783	1,130
36	1903	...do...	55	12.2	....	1.25	27.2	Taper.	296
37	1902	...do...	50	10.8	....	.962	23.67	Taper.	200
38	1898	...do...	50	10.25	....	.891	23.67	Taper.	200

Description No. (46)	Pitch, rifle. (47)	Muzzle velocity. (48)	Number of grooves. (49)	Width of groove. (50)	Depth of groove. (51)	Width of land. (52)	Muzzle energy. (53)
		Ft. per sec.		*Inch.*	*Inch.*	*Inch.*	*Ft. tons.*
1	1/50–1/25	2,700	144	0.2091	0.12	0.14	121,430
2	1/50–1/25	2,700	144	.2091	.12	.14	121,430
3	1/50–1/25	2,700	144	.2091	.12	.14	121,430
4	1/50–1/25	2,250	96	.3736	.06	.15	84,328
5	1/50–1/25	2,150	126	.2091	.07	.14	53,259
5A	1/50–1/25	2,350	126	.2091	.07	.14	63,637
6	1/50–1/25	2,350	126	.2091	.07	.14	....
7	1/50–1/25	2,350	126	.2091	.07	.14	63,637
8	1/32	....	136	.1734	.12	.15	....
9	1/20	1,500	108	.2091	.06	.14	10,935
10	1/40–1/20	1,500	72	.3736	.06	.15	10,935
10A	1/40–1/20	1,800	108	.2091	.06	.14	15,742
11	1/50–1/25	2,250	72	.3736	.06	.15	36,754
12	1/50–1/25	2,235	72	.3736	.06	.15	36,103
13	1/50–1/25	2,250	72	.3736	.06	.15	36,754
14	1/50–1/25	2,250	72	.3736	.06	.15	36,754
15	1/50–1/25	2,235	72	.3736	.06	.15	36,103
16	1/50–1/25	2,250	72	.3736	.06	.15	36,754
17	1/40–1/20	1,500	72	.3736	.06	.15	10,935
18	1/40–1/20	1,950	108	.2091	.06	.14	18,474
19	0–1/25	2,250	90	.2091	.07	.14	21,223

[1] Data is for first stated model.

GUN—Continued.

Description No. 46	Pitch, rifle. 47	Muzzle velocity. 48	Number of grooves. 49	Width of groove. 50	Depth of groove. 51	Width of land. 52	Muzzle energy 53
		Ft. per sec.		Inch.	Inch.	Inch.	
20	1/50-1/25	2,265	60	0.3736	0.06	0.15	21,452
21	1/50-1/25	2,250	60	.3736	.06	.15	21,223
22	1/50-1/25	2,250	60	.3736	.06	.15	21,223
23	1/50-1/25	2,250	60	.3736	.06	.15	10,615
24	1/50-1/25	2,200	48	.3736	.06	.15	10,615
25	1/50-1/25	2,200	48	.3736	.06	.15	9,372
26	1/50-1/25	2,600	48	.3736	.06	.15	4,973
27	1/50-1/25	2,600	54	.2091	.05	.14	4,973
28	0-1/25	2,600	54	.2091	.05	.14	4,973
29	0-1/25	2,600	54	.2091	.05	.14	4,973
30	1/50-1/25	2,600	36	.3736	.04	.15	4,973
31	1/50-1/25	2,600	36	.3736	.04	.15	4,973
32	1/50-1/25	2,600	54	.2091	.05	.14	4,973
33	....	....	....	....	....	....	....
34	0-1/30	....	24	....	.05	....	....
35	1/20	900	42	.2116	.04	.14	4.973
36	1/50-1/25	2,600	24	.2927	.03	.10	703.8
37	1/50-1/25	2,600	24	.2927	.03	.10	702
38	1/50-1/25	2,600	24	.2927	.03	.10	....

Description No. 54	Breech. Type. 55	Breech. Model. 56	Breech. Swing. 57	Breech. Power, open. 58	Breech. Power, closing. 59	Firing mechanism. Type. 60	Firing mechanism. Model. 61
1	A	1907	Down	Hand	Air	Combined	1903
2	A	1907	Side	do	Hand	do	1903
3	A	1907	Down	do	Air	do	1903
4	B	1895	Side	do	Hand	do	1903
5	A	1907	do	do	do	do	1903
5A	A	1907	do	do	do	do	1903
6	A	1909	do	do	do	do	1903
7	A	1907	do	do	do	do	1903
8	A	1907	Down	do	Air	do	1903
9	B	1908	Side	do	Hand	do	1903
10	B	1890	do	do	do	do	1903
10A	B	1908	do	do	do	do	1903
11	B	1895	do	do	do	do	1903
12	B	1888	do	do	do	do	1903
13	B	1895	do	do	do	do	1903
14	B	1895	do	do	do	do	1903
15	B	1888	do	do	do	do	1903
16	B	1895	do	do	do	do	1903
17	B	1890	do	do	do	do	1903
18	A	1907	do	do	do	do	1903
19	B	1895	do	do	do	do	1903
20	B	1895	do	do	do	do	1903
21	B	1888	do	do	do	do	1903
22	B	1888	do	do	do	do	1903
23	B	1888	do	do	do	do	1903
24	B	1888	do	do	do	do	1903
25	B	1888	do	do	do	do	1903
26	B	1888	do	do	do	do	1903
27	B	1908	do	do	do	do	1903
28	Cone	1903	do	do	do	do	1903
29	Cone	1905	do	do	do	do	1903
30	B	1900	do	do	do	do	1903
31	B	1897	do	do	do	do	1903
32	B	1908	do	do	do	do	1903
33	....	....	do	do	do	do	1903
34	Cone	....	do	do	do	do	1903
35	....	....	do	do	do	Continuous	1903
36	B	1903	do	do	do	....	1903
37	B	....	do	do	do	Continuous	1903
38	B	....	do	do	do	do	1903

A. Stepped thread. B. Single thread.

AMMUNITION.

Description No.	Projectile.	Weight.		Length.		Projectile.	Weight.		Length.		Projectile.	Weight.		Length.	
		Projectile.	Powder.	Projectile.	Charge.		Projectile.	Powder.	Projectile.	Charge.		Projectile.	Powder.	Projectile.	Charge.
62	63	64	65	66	67	68	69	70	71	72	73	74	75	76	77
	Type.	*Pounds.*	*Pounds.*	*Inches.*	*Inches.*	*Type.*	*Pounds.*	*Pounds.*	*Inches.*	*Inches.*	*Type.*	*Pounds.*	*Pounds.*	*Inches.*	*Inches.*
1	C. I. shot	2,400	850	71.5	118	A. P. shell	2,400	850	71.5	118	A. P. shot	2,400	850	64.25	118
2	do	2,400	850	71.5	118	do	2,400	850	71.5	118	do	2,400	850	64.25	118
3	do	2,400	225	71.5		do	2,400	225	71.5		do	2,400	225	64.25	
4	do	2,400	666.5	71.5	102	do	2,400	666.5	71.5	102	do	2,400	650	64.25	102
5	do	1,660	336.2	62.72	67	do	1,660	336.2	62.72	67	do	1,660	336.2	56.32	67
5A	do	1,660	421.2	62.72	83	do	1,660	421.2	62.72	83	do	1,660	421	56.32	83
6	do	1,660	436.2	62.72	85	do	1,660	436.2	62.72	85	do	1,660	436.2	56.32	85
7	C. S. shell	1,200	420	61.05											
8	C. I. shot	1,660	488	62.72	92	A. P. shell	1,660	470	62.72	92	A. P. shot	1,660	480	54.32	92
9	C. I. shell	1,040	65	37.11	21	D. P. shell	824	65	38.08	21	Torp. shell	1,000	65	56.66	21
10	do	1,040	65	37.11	21	do	824	65	38.08	21	do	1,000	65	56.66	21
10A	do	1,040	89	37.11	28.8	do	824	89	38.08	28.8	do	1,000	89	56.66	28.8
11	do	1,046	255	49.27	62	A. P. shot	1,046	279	43.32	62	A. P. shell	1,046	255	49.27	62
12	do	1,046	279	49.27	62	do	1,046	279	43.32	62	do	1,046	279	49.27	62
13	do	1,046	318	49.27	83	do	1,046	334	43.32	83	do	1,046	334	49.27	83
14	do	1,046	262	49.27	73.5	do	1,046	279	43.32	73.5	do	1,046	262	49.27	73.5
15	do	1,040	262	49.27	73.5	do	1,046	279	43.32	73.5	do	1,046	262	49.27	73.5
16	C. S. shot	700	279	44.95	73.5										
17	do	700	65	44.95	21										
18	do	700	95	44.95											
19	C. I. shot	604	178	41.005	65.75	A. P. shot	604	178	36.19	65.75	A. P. shell	604	178	41.005	65.75
20	do	604	158	41.005	62	do	604	158	36.19	62	do	604	158	41.005	62
21	do	604	158	41.005	62	do	604	158	36.19	62	do	604	158	41.005	62
22	do	604	162	41.005	62	do	604	162	36.19	62	do	604	162	41.005	62
23	do	604	162	41.005	62	do	604	162	36.19	62	do	604	162	41.005	62
24	do	316	83.5	33.53	48.5	do	316	83.5	29.45	48.5	do	316	83.5	33.53	48.5
25	do	316	83.5	33.53	48.5	do	316	70	29.45		do	316	70	33.53	
26	C. S. shrap.	200	70	27.16		Semi S. S.	200	32	25.78		C. S. S. gas.	200	32	26.66	
27	A. P. shot	106	32	18.28		A. P. shell	106	29.75	20.01		R. A. P. shot	106	32	21.24	
28	do	106	32	18.28		do	106	32	20.01		do	106	29.75	21.24	
29	do	106	32	18.28		do	106	29.75	20.01		do	106	32	21.24	
30	do	106	32	18.28	40	do	106	32	20.01	40	do	106	32	21.24	40
31	do	106	29.75	18.28	31	do	106	29.75	20.01	31	do	106	29.75	21.24	31
32	do	106	29.75	18.28	31	do	106	29.75	20.01	31	do	106	29.75	21.24	31
33	do	106	32	18.28		do	106	32	20.01		do	106	32	21.24	
34	do	106	17.75	18.28		do	106	17.75	20.01		do	106	17.75	21.24	
35	C. I. shot	45	3.75	12.7		do	45	3.75	13.8		Shrapnel	45	3.75	13.25	
36	do	15	5.5	10.21		S. shell	15	5.5	10.6						
37	do	15	.5	10.21		do	15	5	10.6						
38	do	15	.5	10.21		do	15	5	10.6						

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